

図1 Fig.1

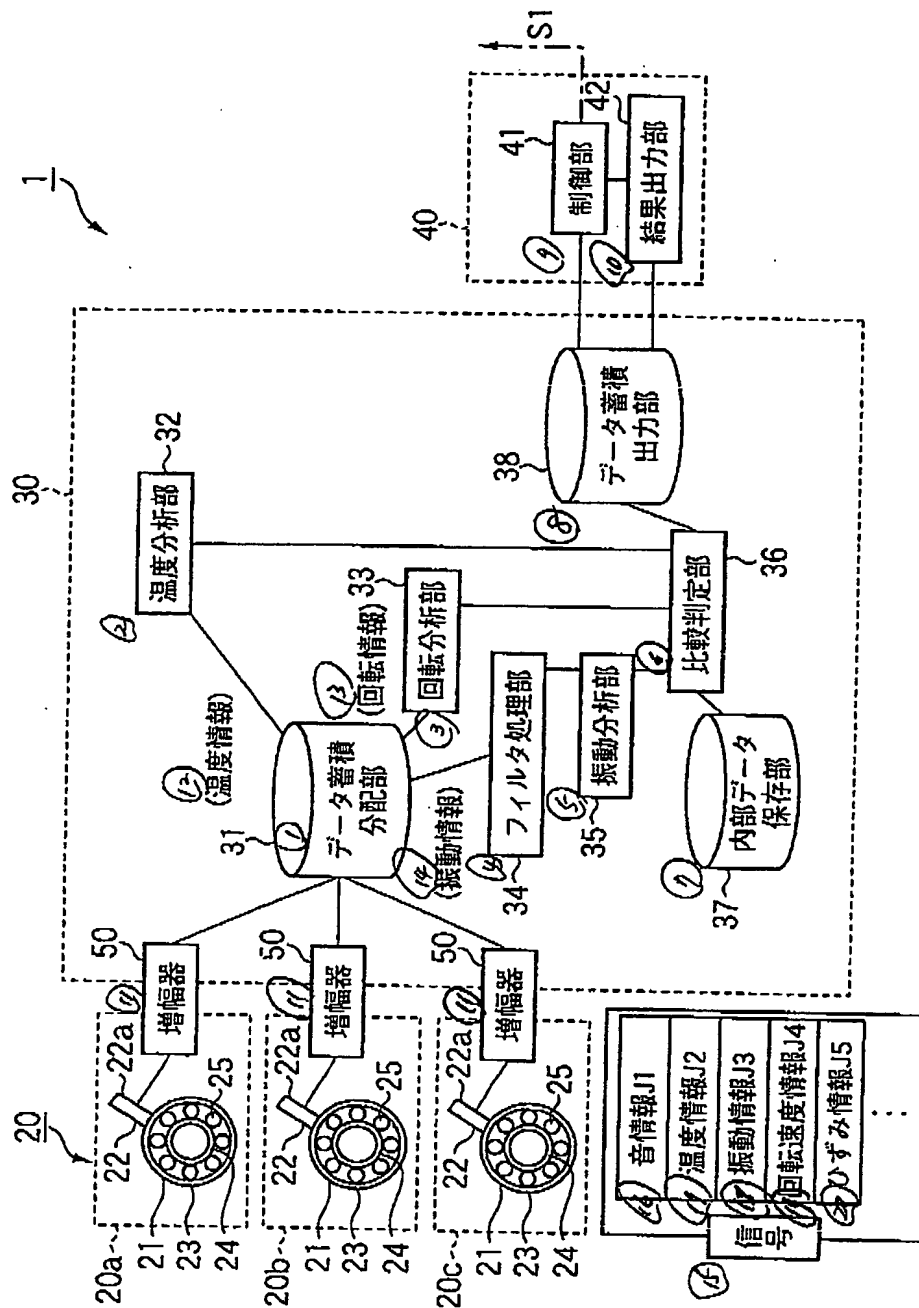
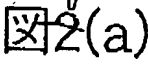


Fig. 2(a)  
 2(a)

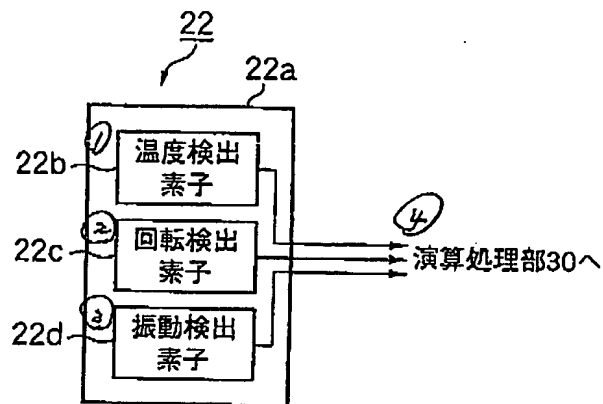
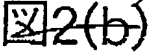


Fig. 2(b)  
 2(b)

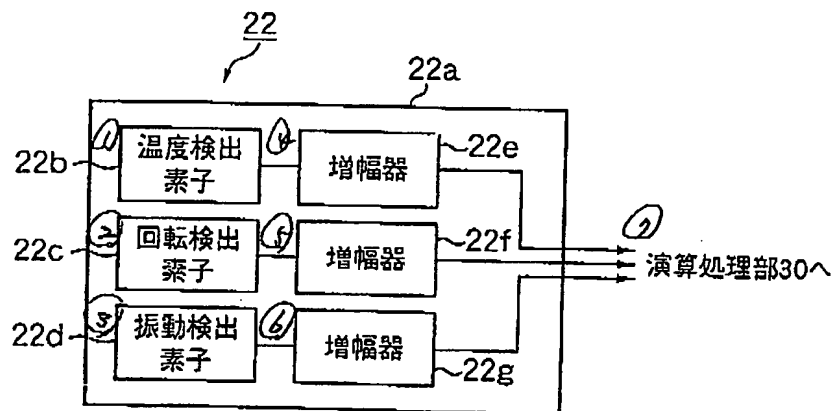


図3 Fig. 3

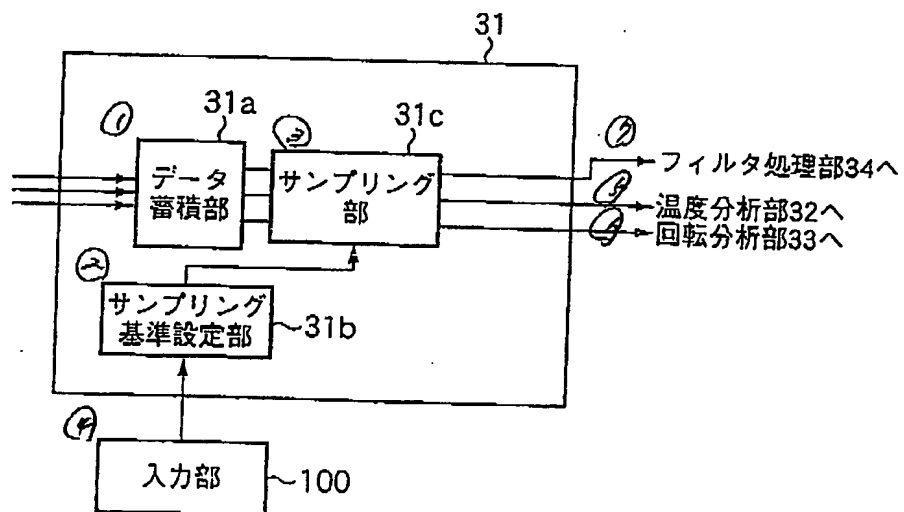


図4 Fig. 4

① 転がり軸受の傷	② エンベロープ処理後の周波数
③ 内輪 (Si)	$Zf_i = \frac{fr}{2} \left( 1 + \frac{Da}{dm} \cos \alpha \right) Z$ [Hz]
④ 外輪 (So)	$Zf_c = \frac{fr}{2} \left( 1 - \frac{Da}{dm} \cos \alpha \right) Z$ [Hz]
⑤ 転動体 (Sb)	$2fb = fr \left( 1 - \frac{Da^2}{dm^2} \cos^2 \alpha \right)$ [Hz]
⑥ 保持器 (Sc)	$fc = \frac{fr}{2} \left( 1 - \frac{Da}{dm} \cos \alpha \right)$ [Hz]

- ⑦  $fr$ : 内輪回転速度 [Hz]    ⑪  $Z$ : 転動体の数  
 ⑧  $fc$ : 保持器回転速度 [Hz]     $fi: fr - fc$   
 ⑨  $fb$ : 転動体自転速度 [Hz]    ⑫  $Da$ : 転動体直径 [mm]  
 ⑩  $dm$ : ピッチ円直径 [mm]    ⑬  $\alpha$ : 接触角 [度]



図6 Fig. 6

① 時間波形

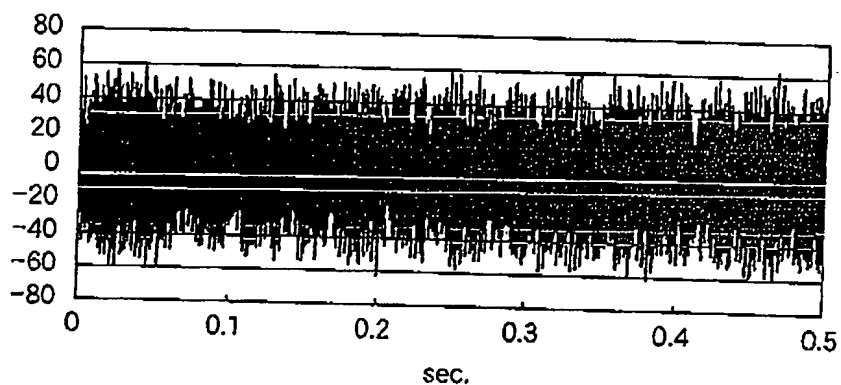


図7 Fig. 7

① FFTスペクトル

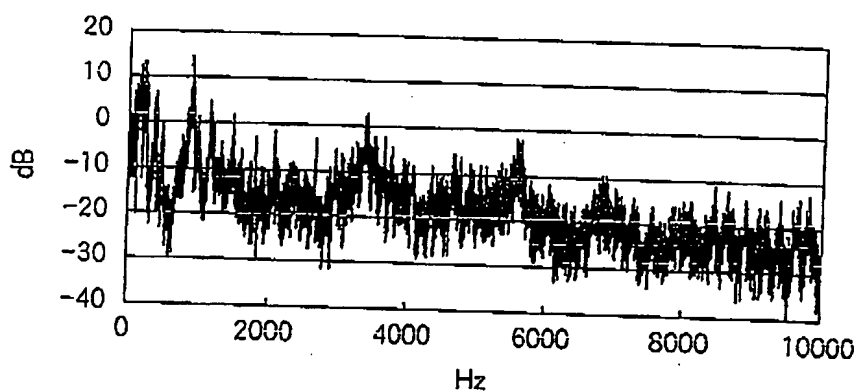


図8 Fig. 8

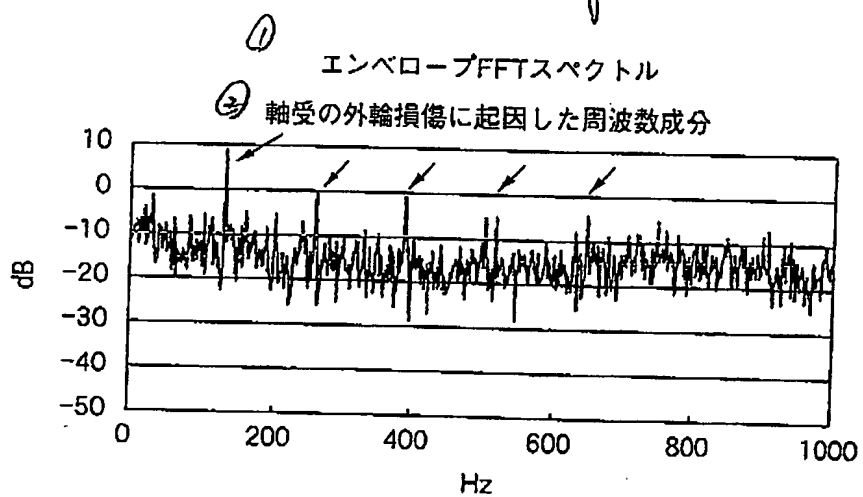


図9 Fig. 9

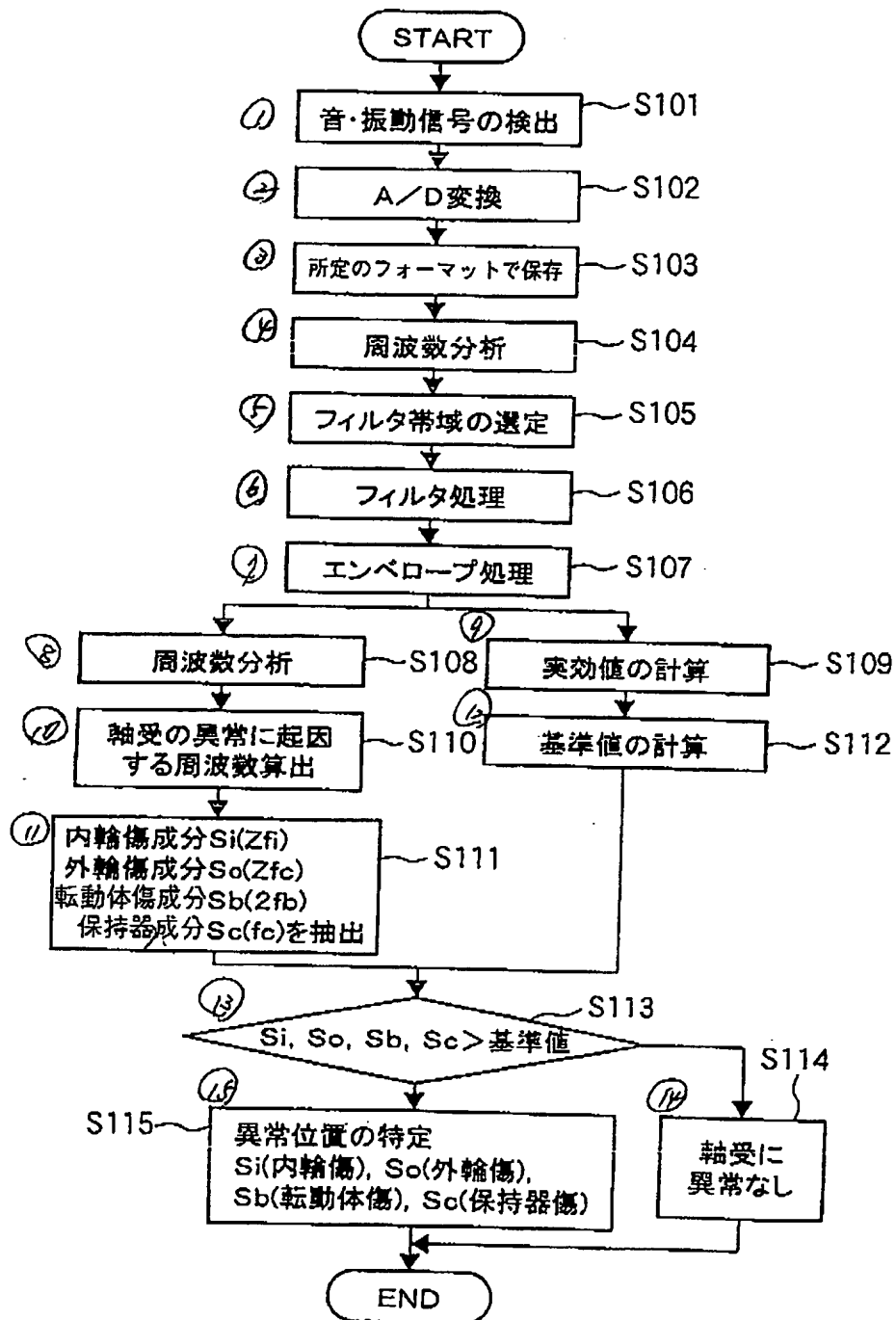




图10 Fig. 10

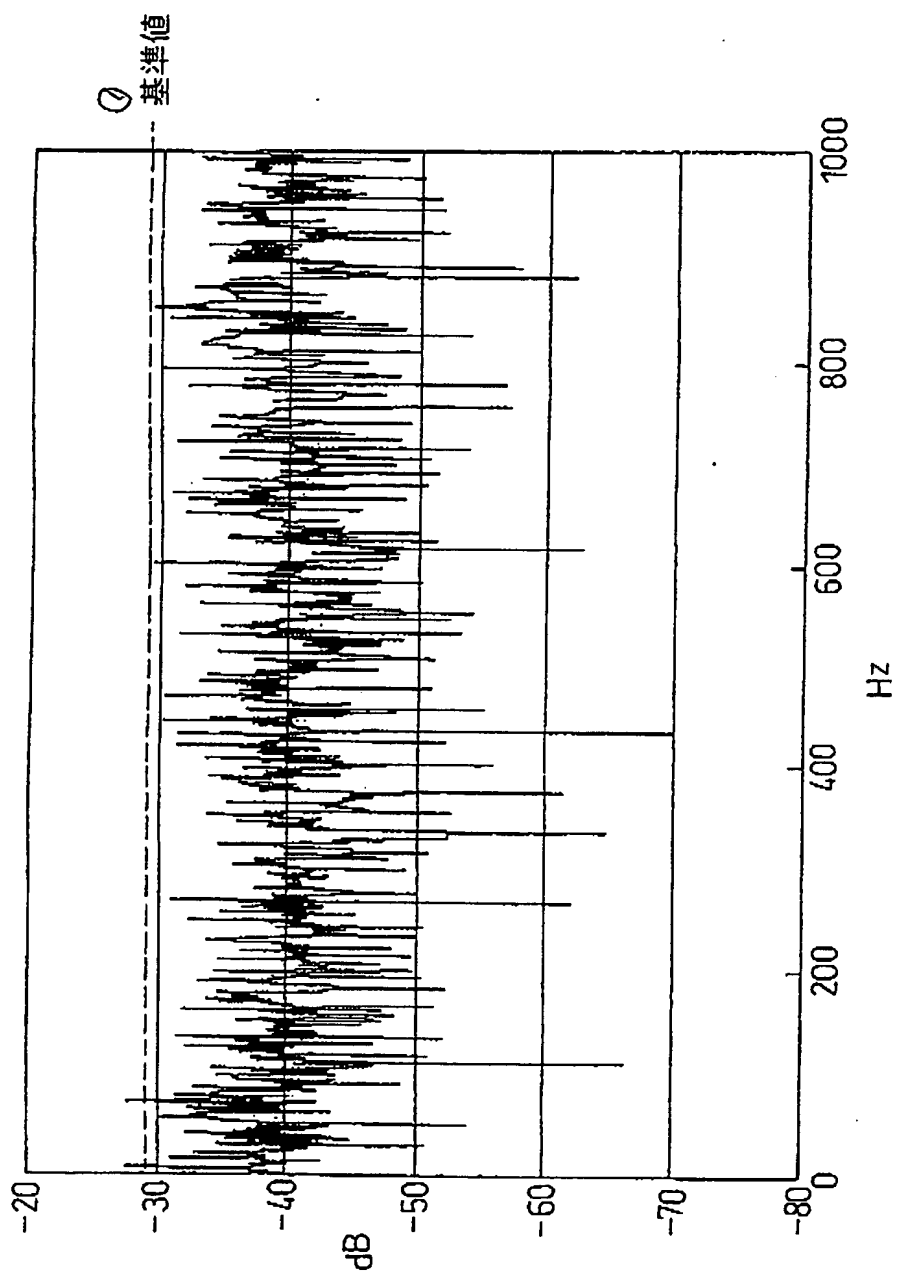


图11 Fig. 11

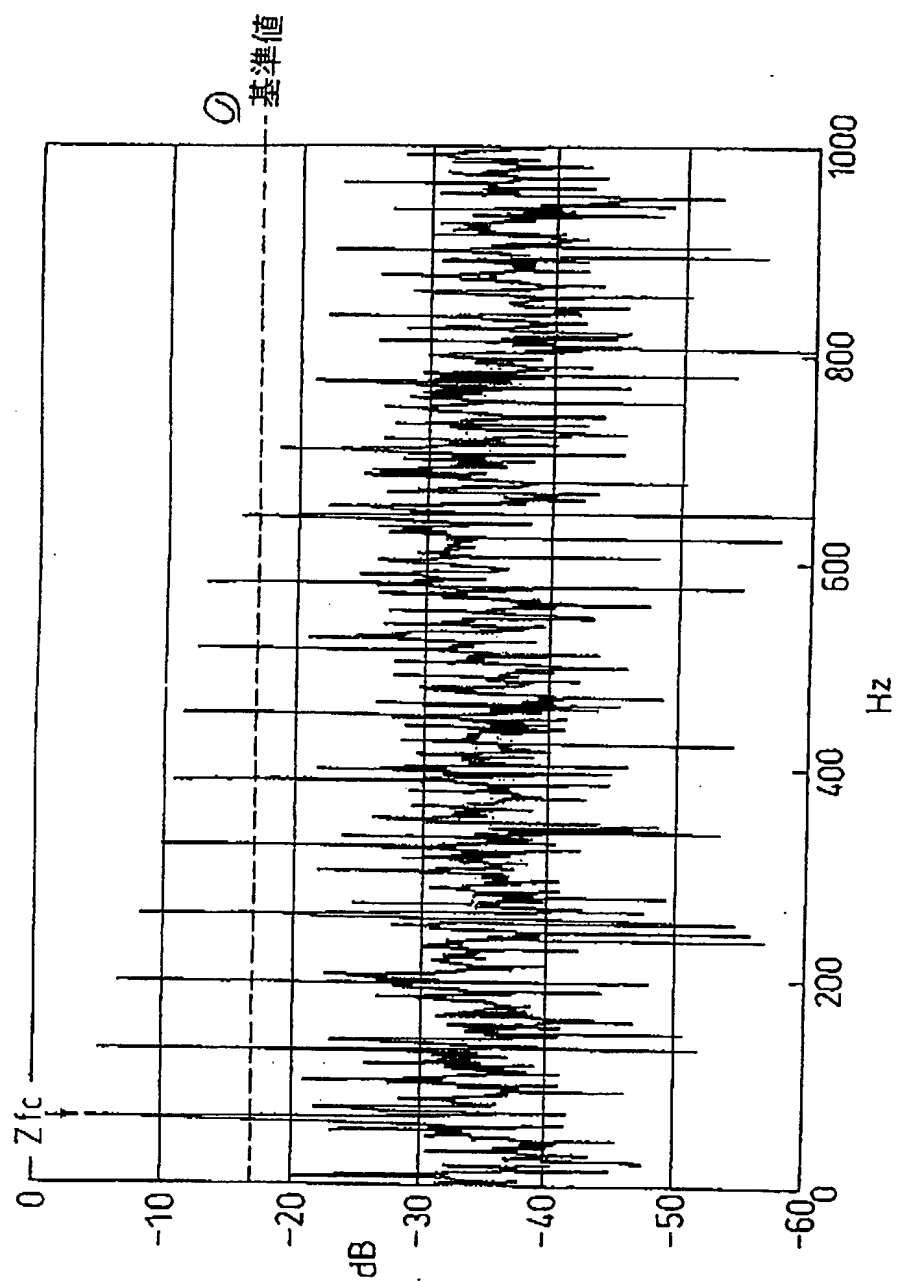


图12 Fig. 12

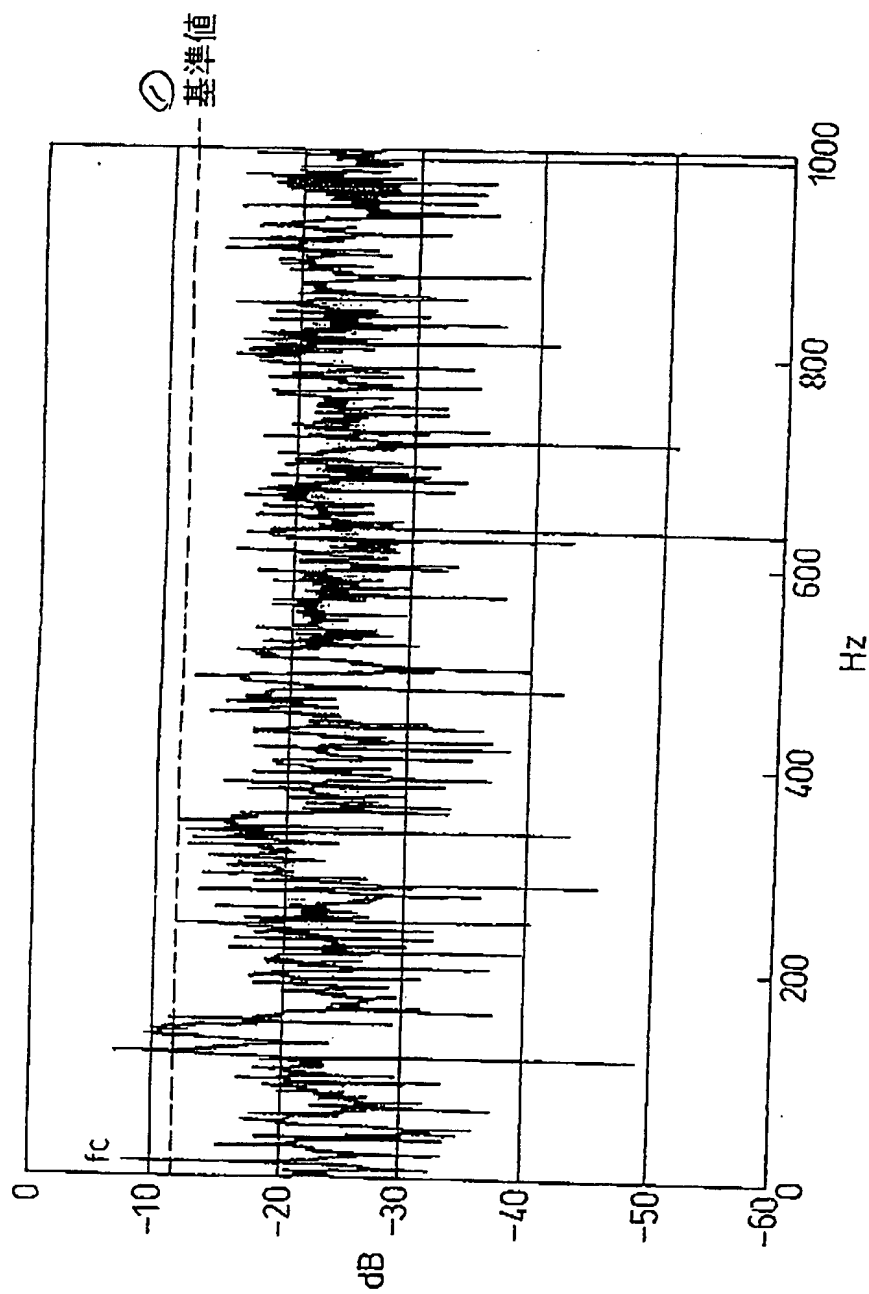


図13 Fig. 13

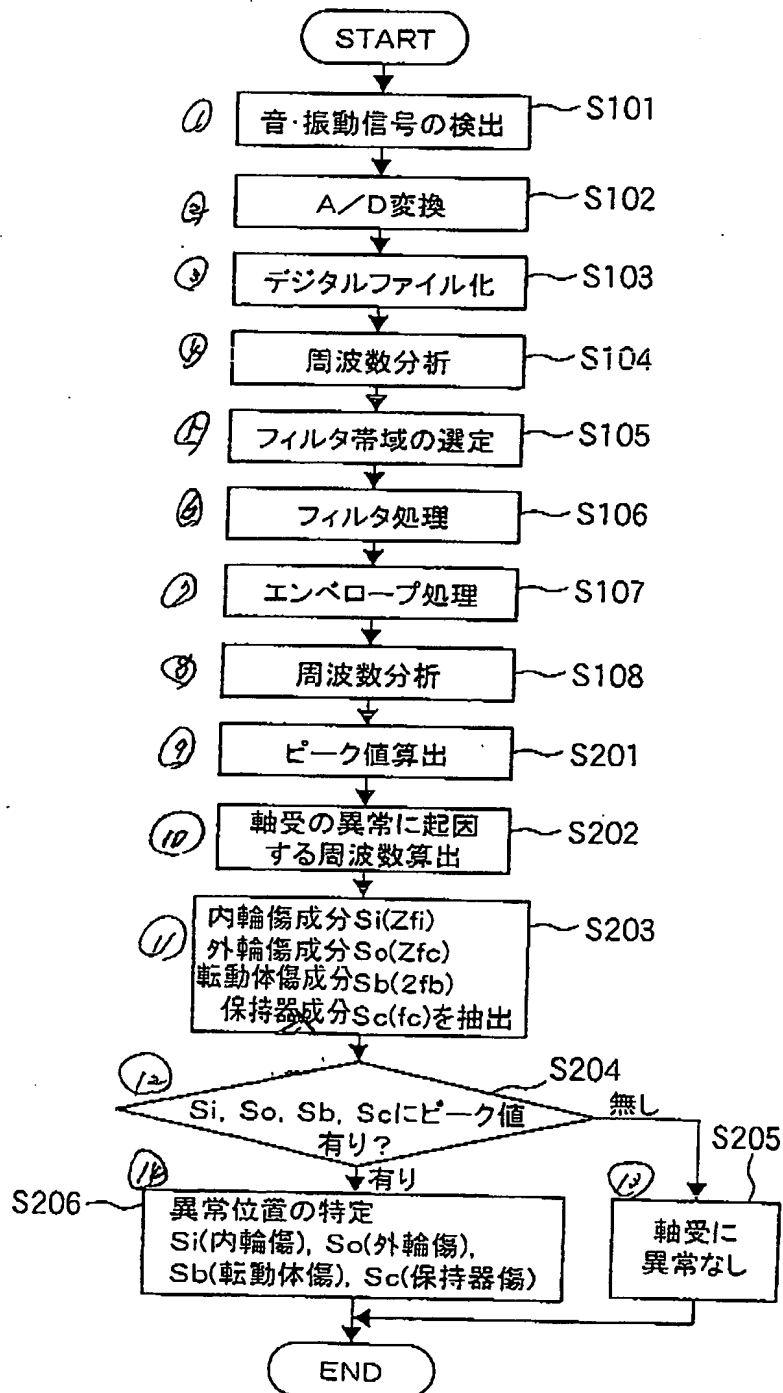
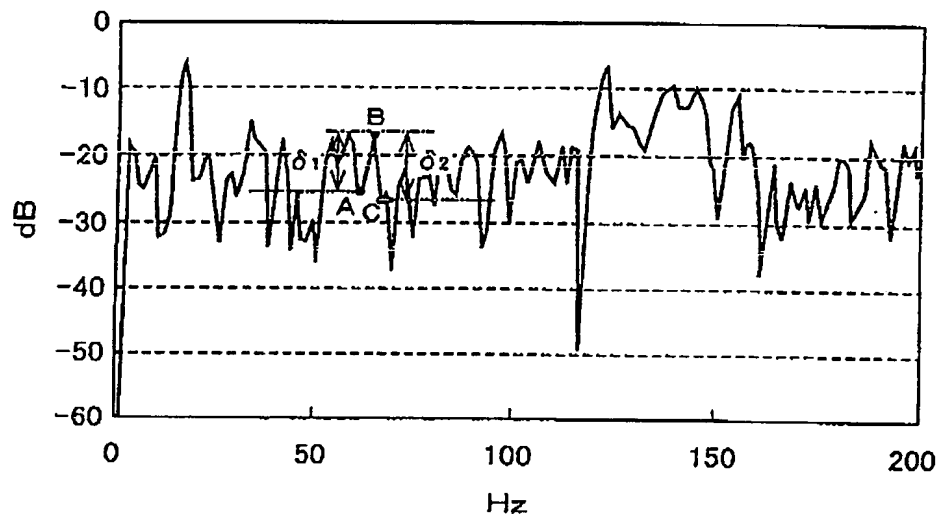


図14 Fig. 14



①

$A(X_0, Y_0), B(X_1, Y_1), C(X_2, Y_2)$ とすると

$$\delta_1 (= Y_1 - Y_0) > 0, \quad -①$$

$$\delta_2 (= Y_2 - Y_1) < 0, \quad -②$$

①, ②を満たし,

$$dy/dx = (Y_1 - Y_0)/(X_1 - X_0) > 1$$

または,

$$dy/dx = (Y_2 - Y_1)/(X_2 - X_1) < -1$$

を満たすとき,  $Y_1$ をピークとする.

図15 Fig. 15

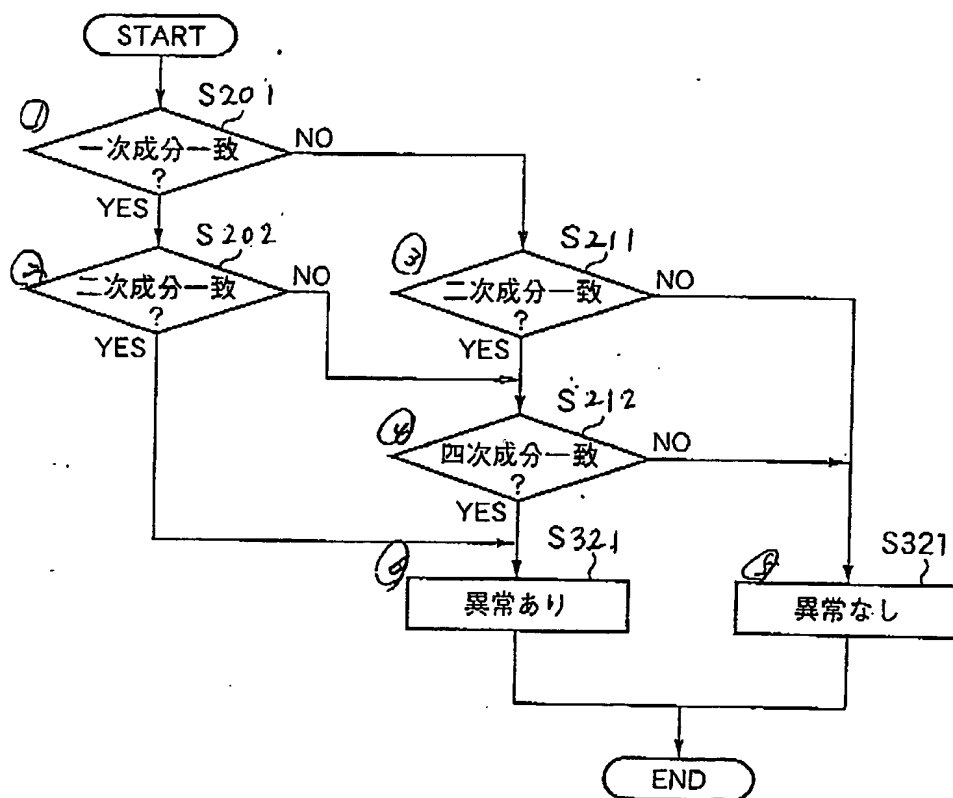


図16 Fig. 16

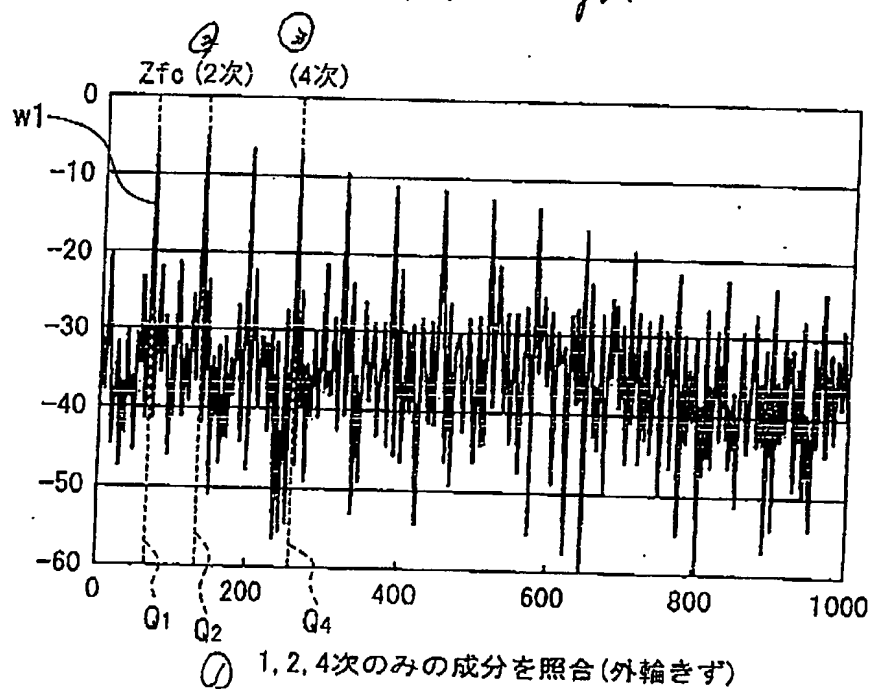


図17 Fig. 17

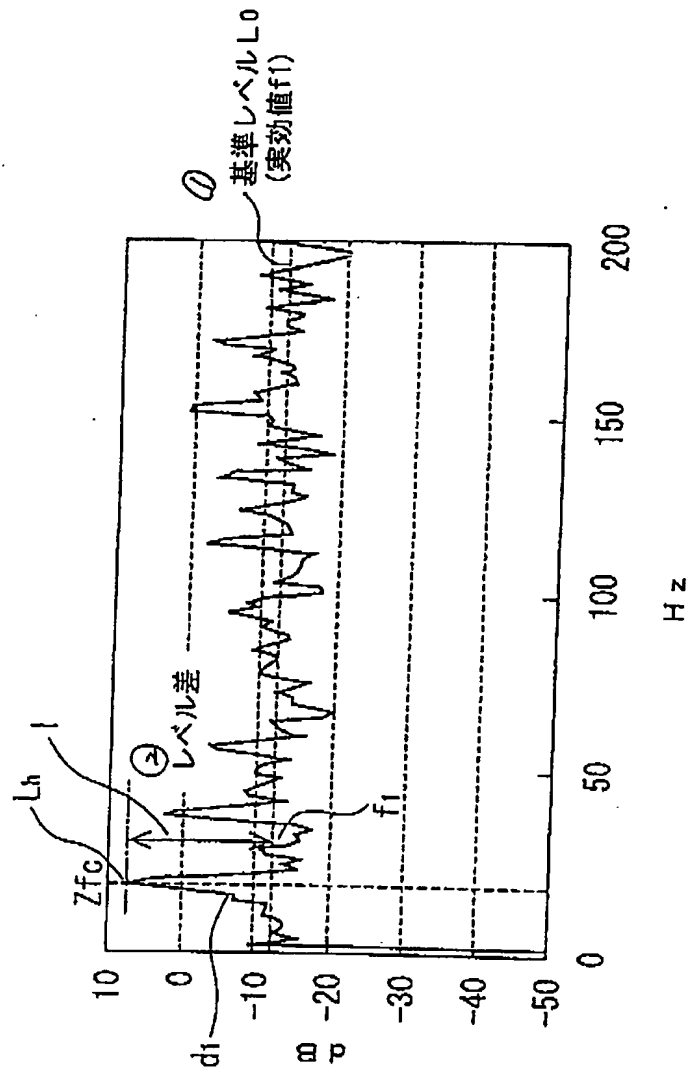




図18 Fig. 18.

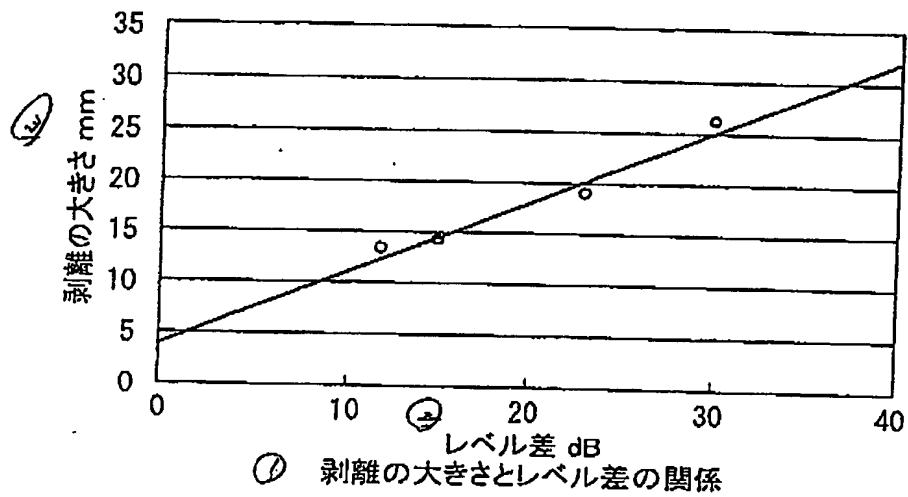


図19 Fig. 19

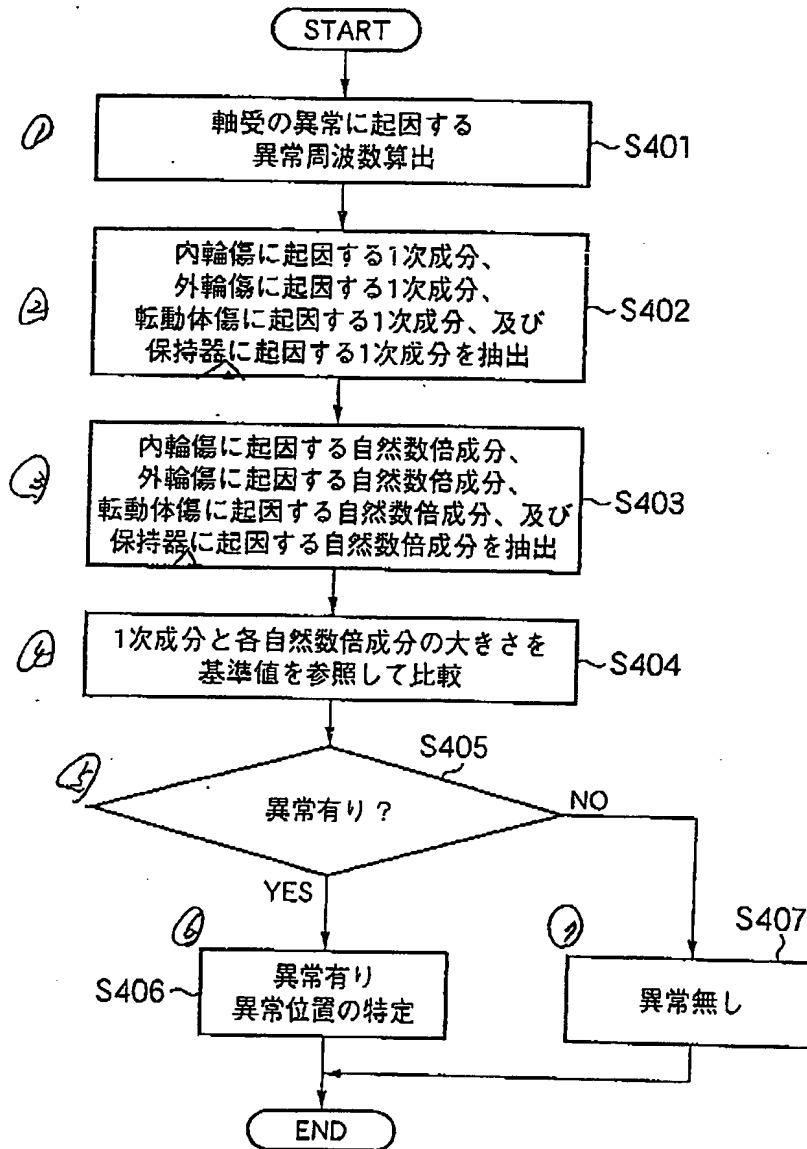


図20 Fig. 20

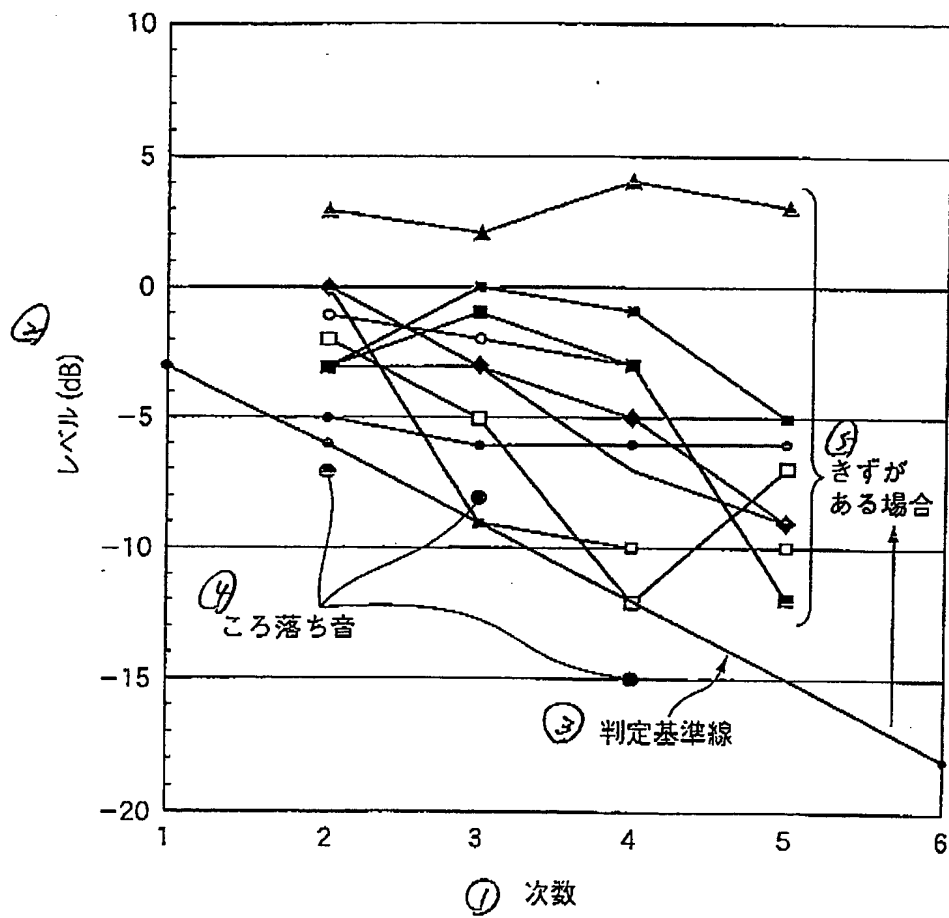


図21 Fig. 21

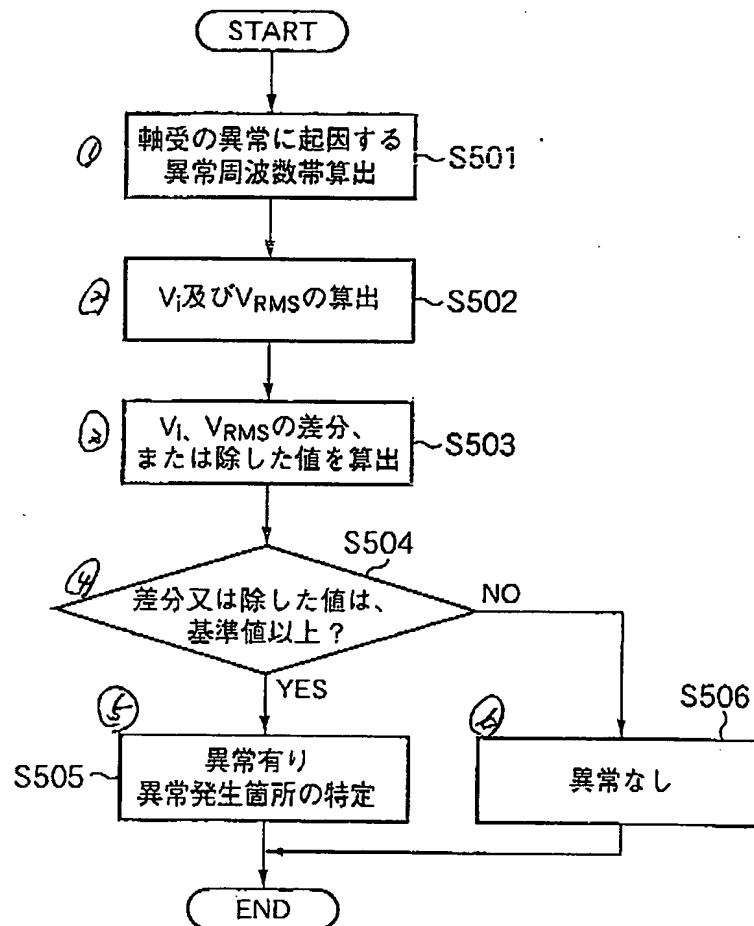


図22 Fig. 22

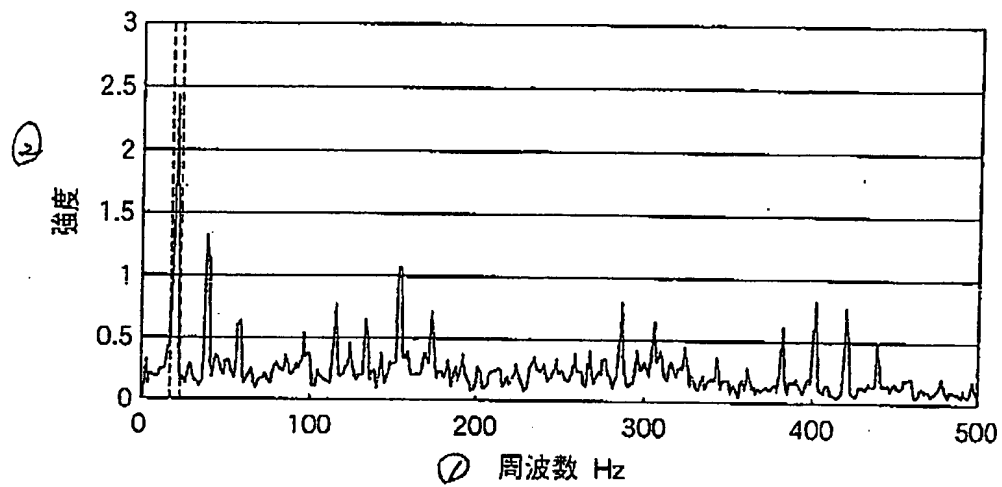


図23 Fig. 23

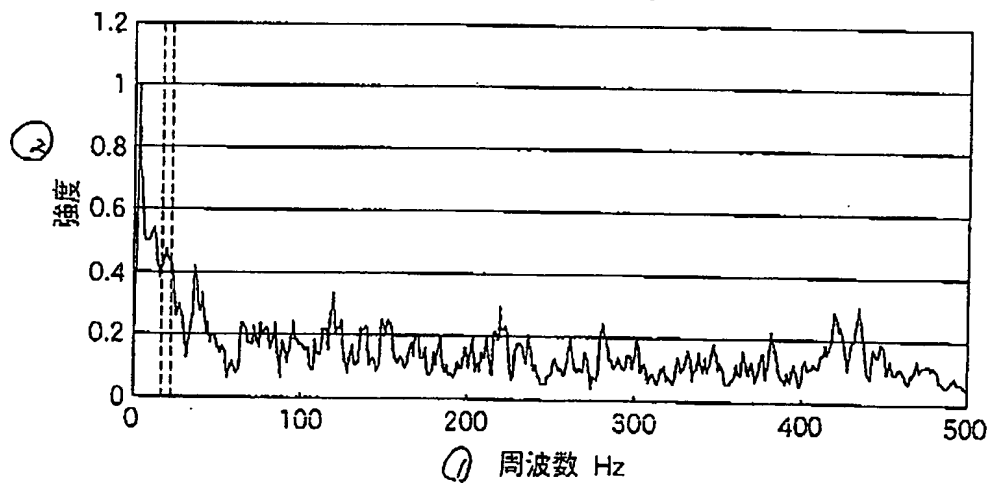


図24 Fig. 24

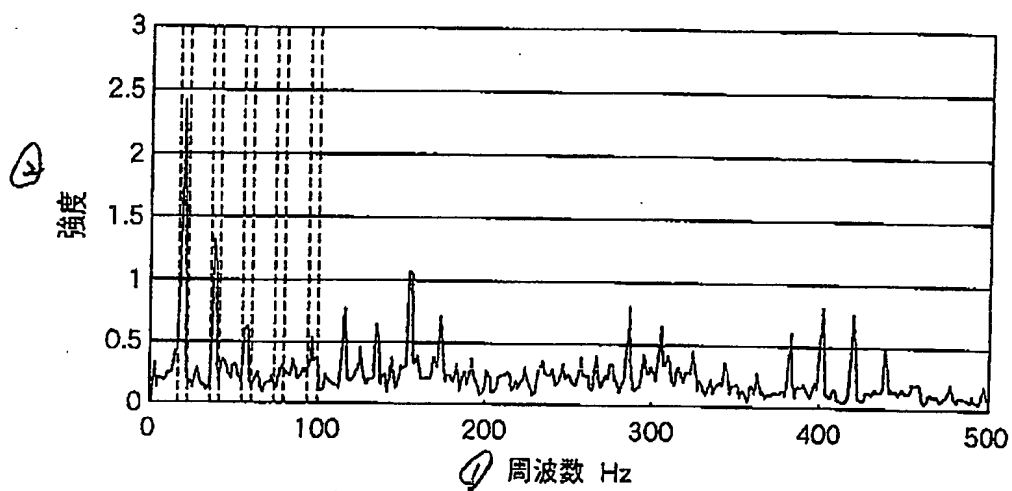


図25 Fig. 25

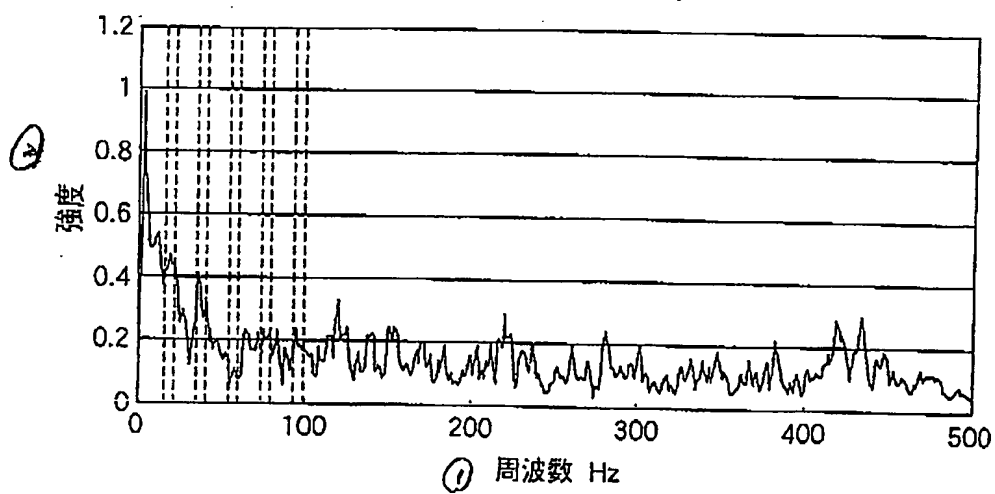


図26 Fig. 26

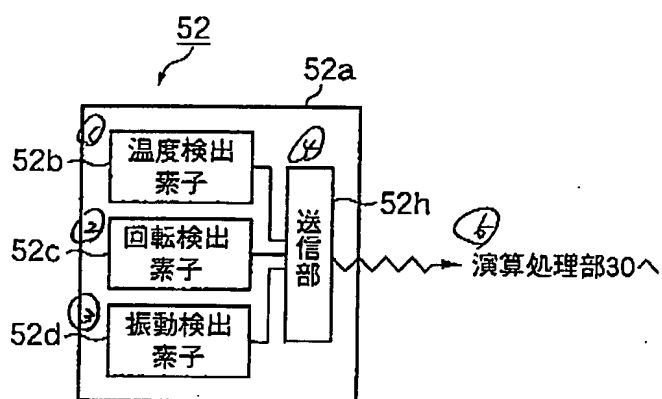


図27 Fig. 27

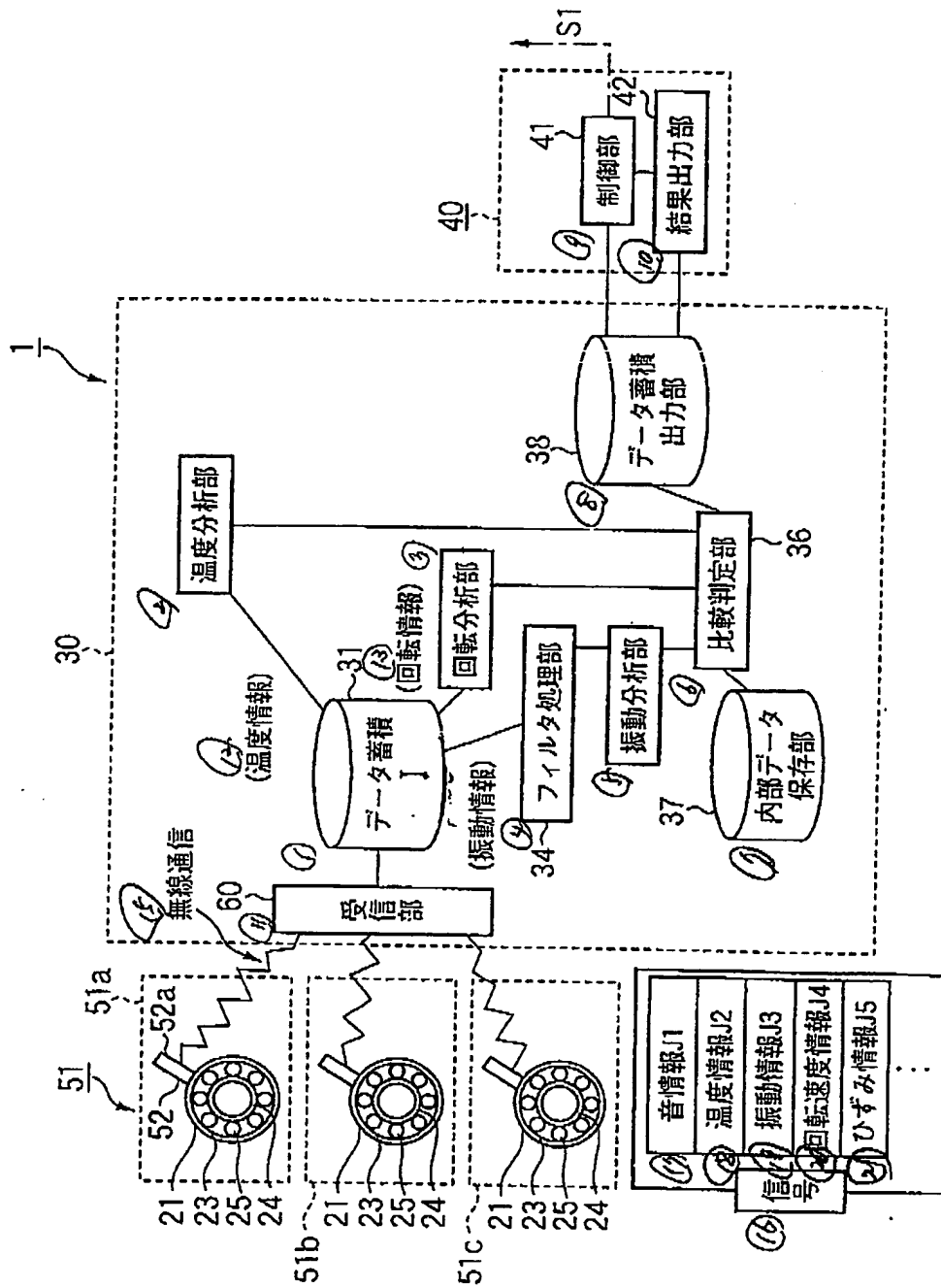




図28 Fig. 28

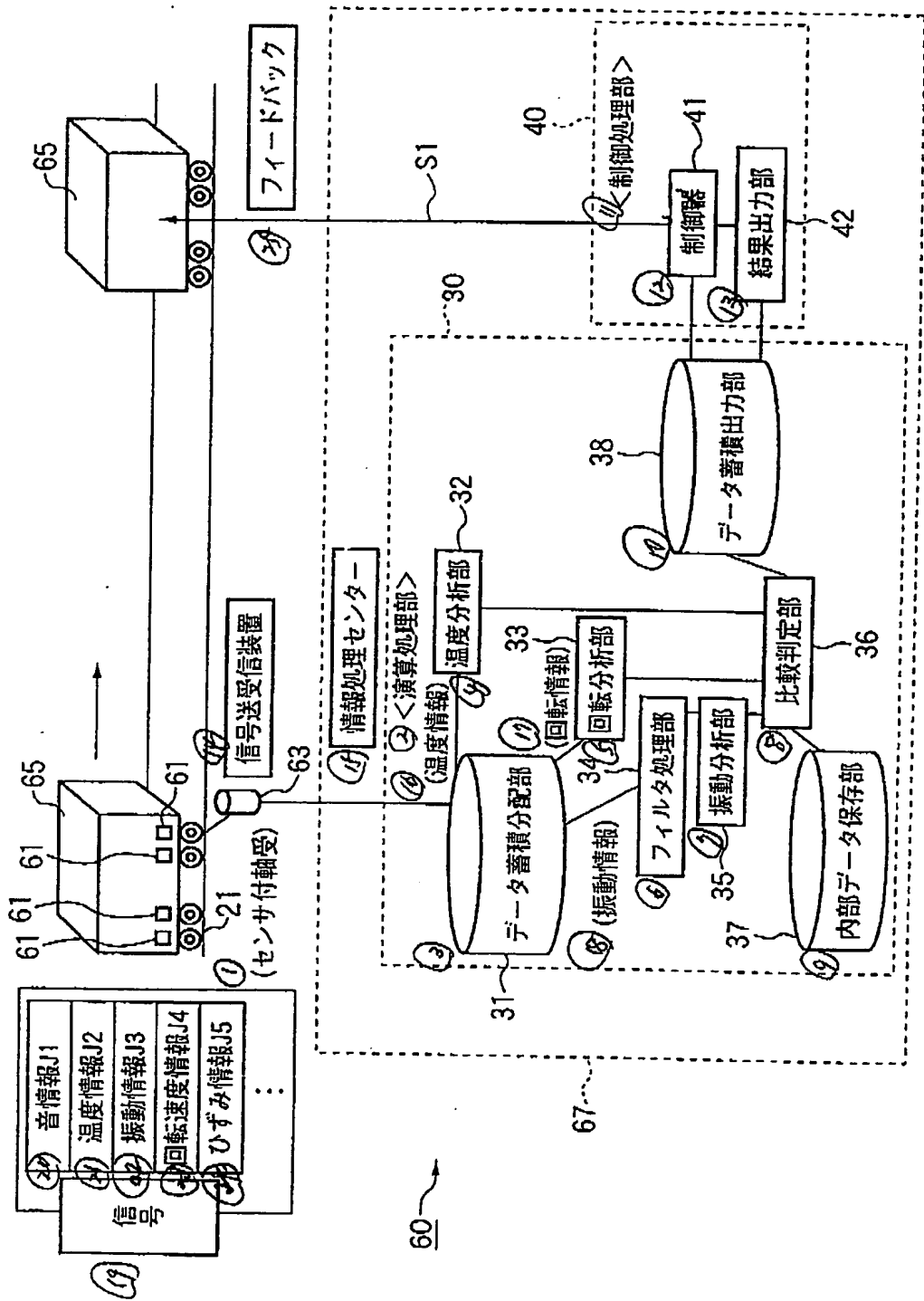


図29 Fig.29

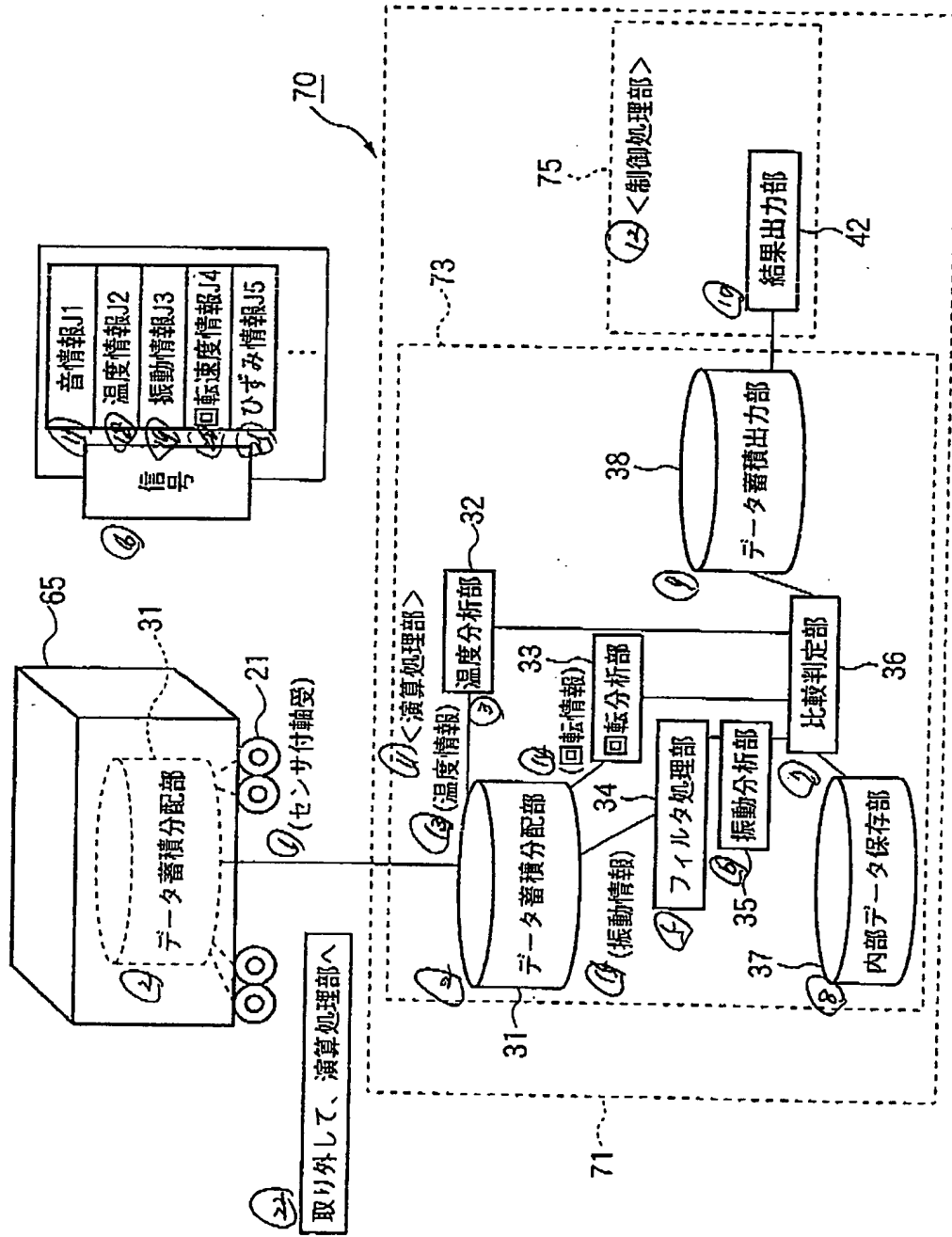


図30 Fig. 30

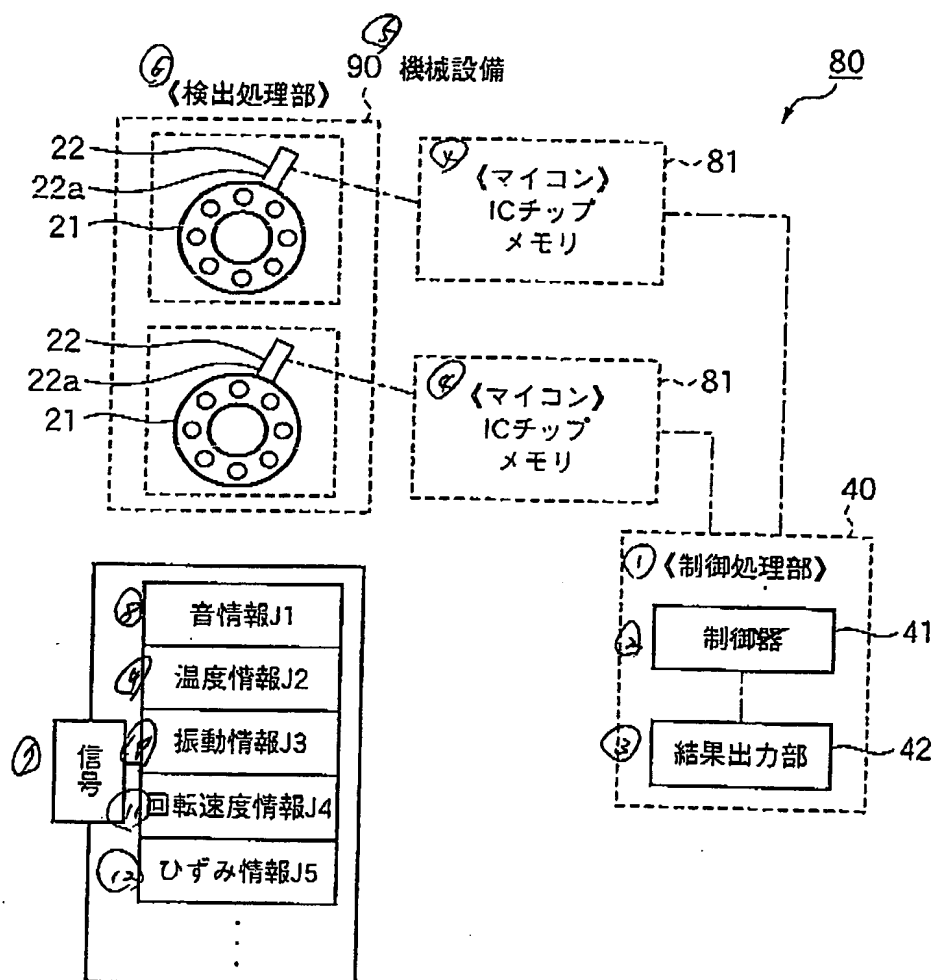


図31 Fig. 31

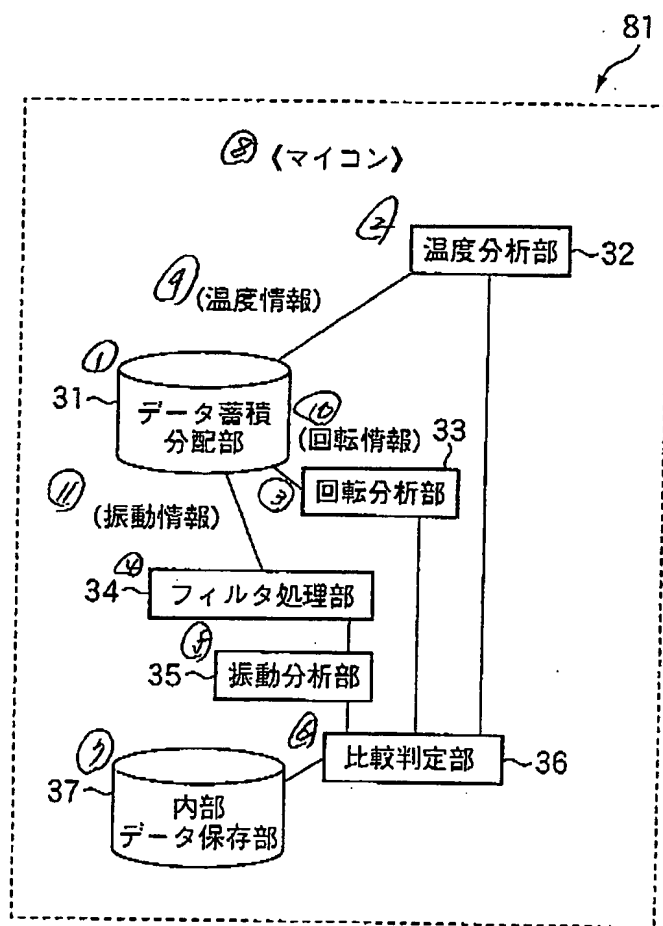


図32 Fig. 32

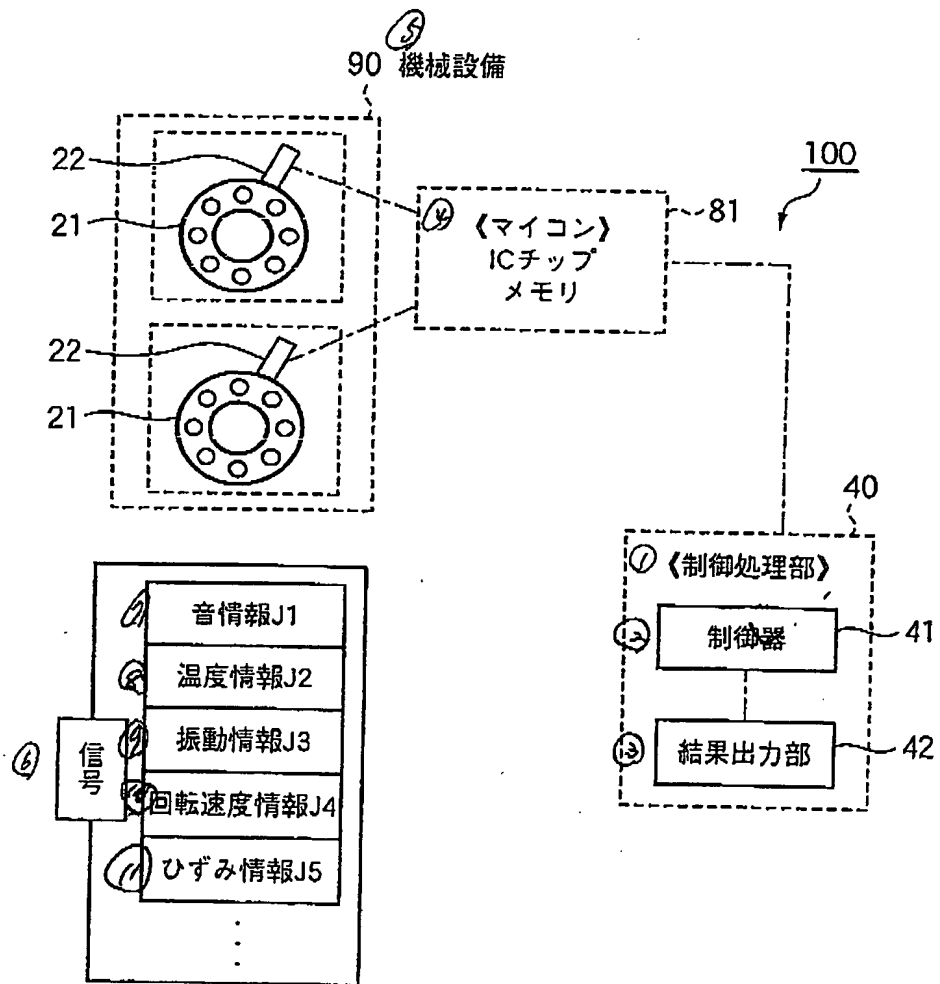


図33 Fig. 33

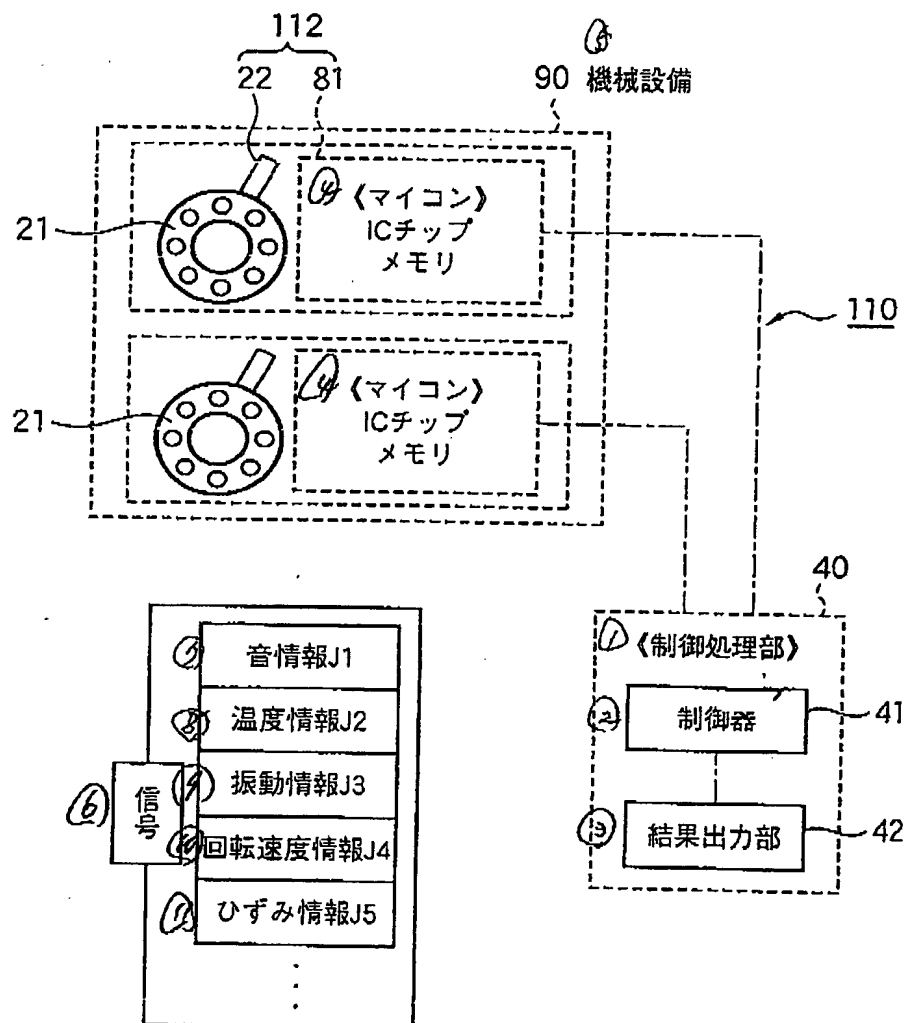


Fig. 34  
34(a)

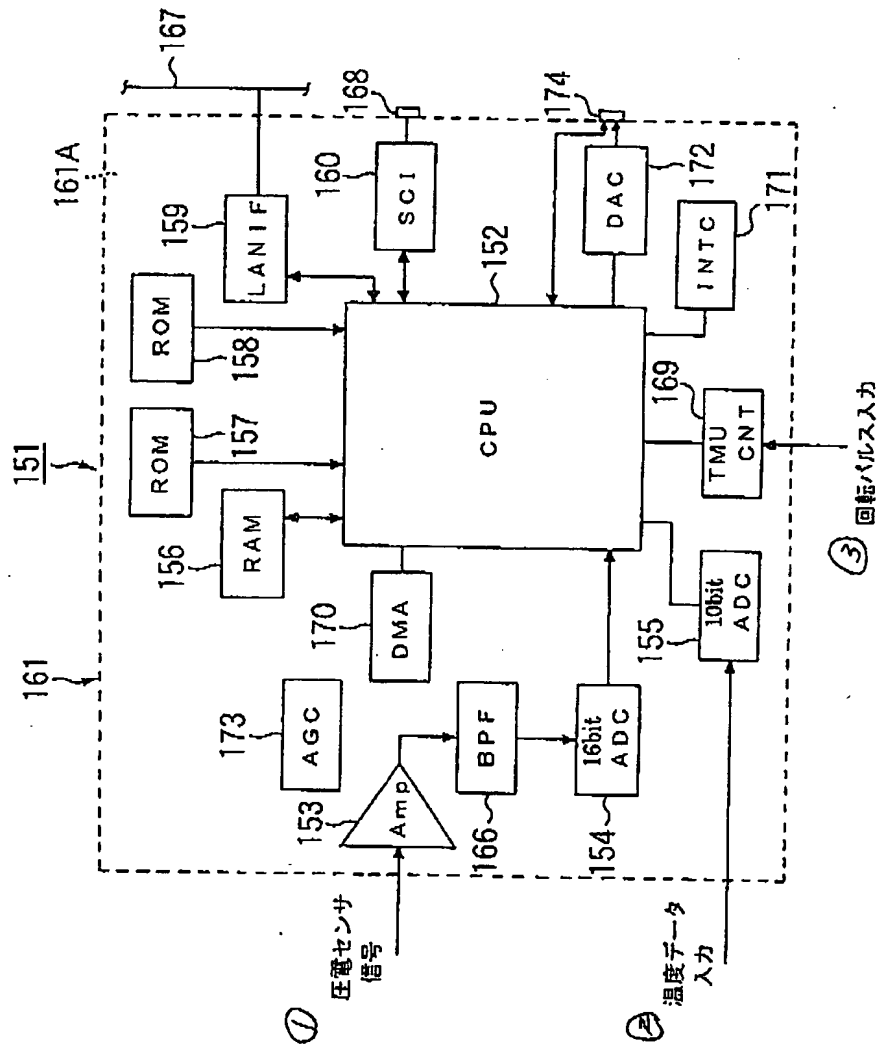


Fig. 34  
34(b)

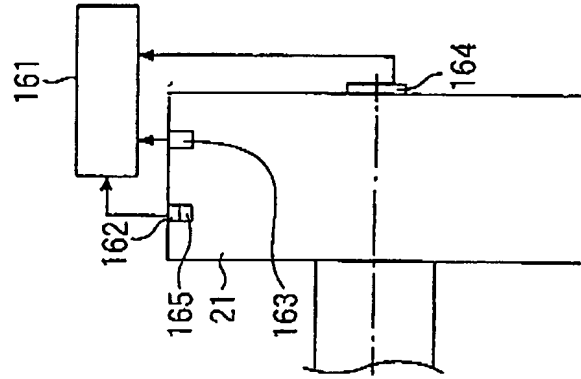


Fig. 35  
図35(b)

Fig. 35  
図35(a)

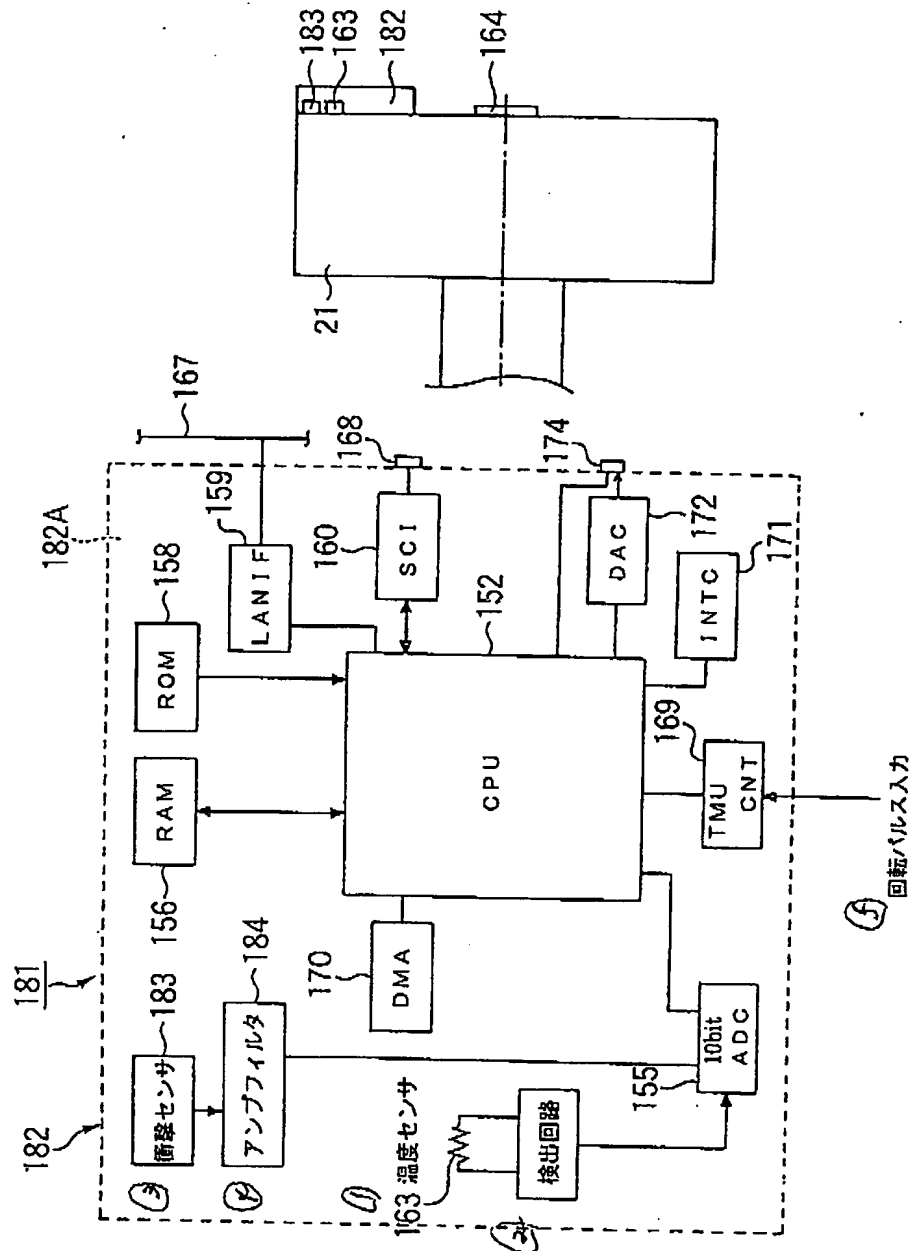




Fig. 36.  
図36

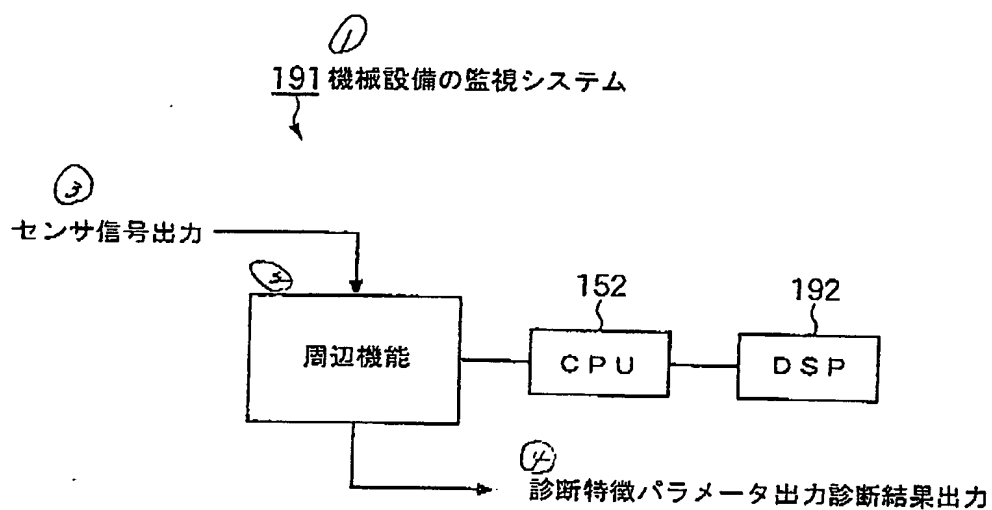


图37 Fig 37

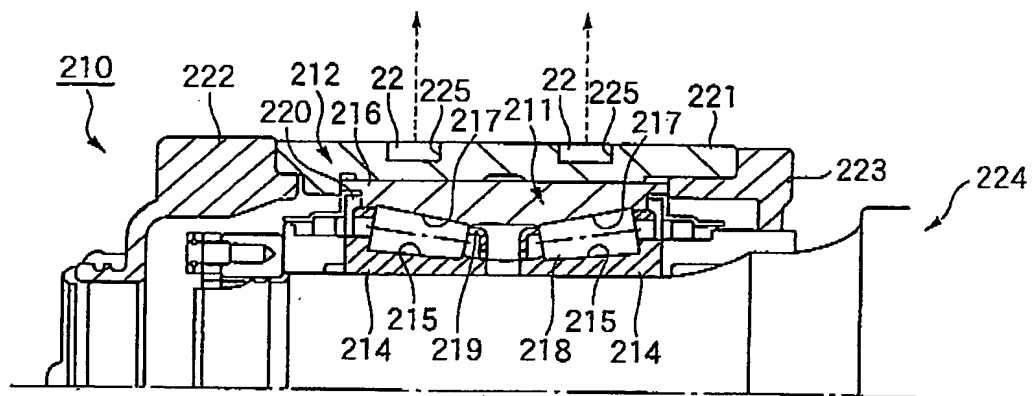


図38 Fig. 38

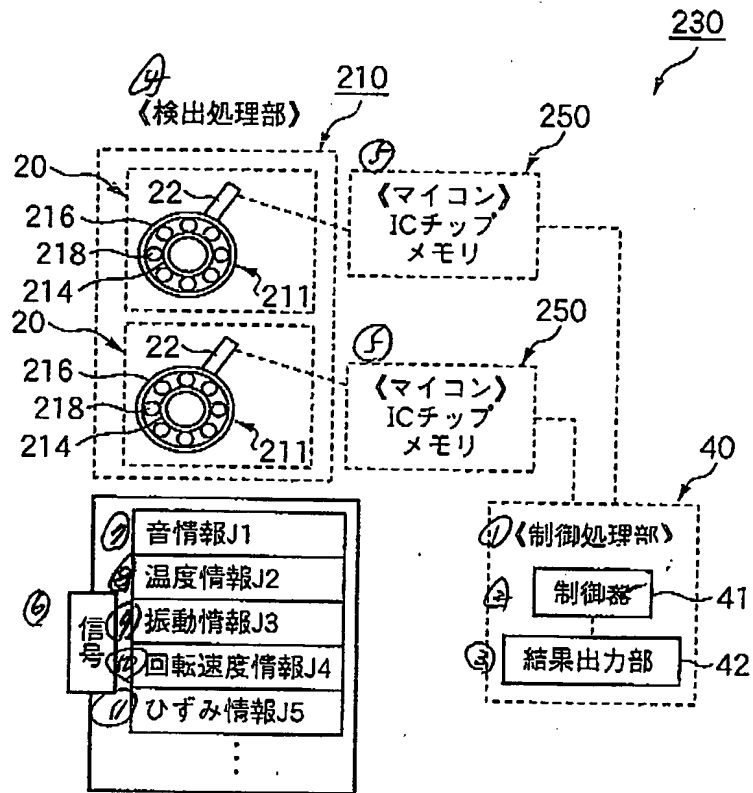


図39 Fig. 39

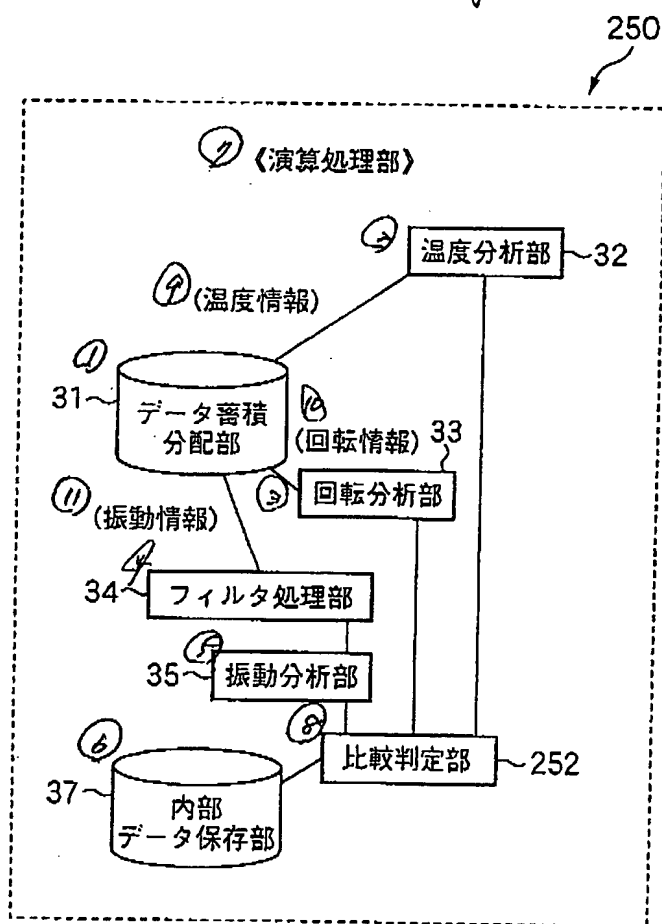


図40 Fig. 40

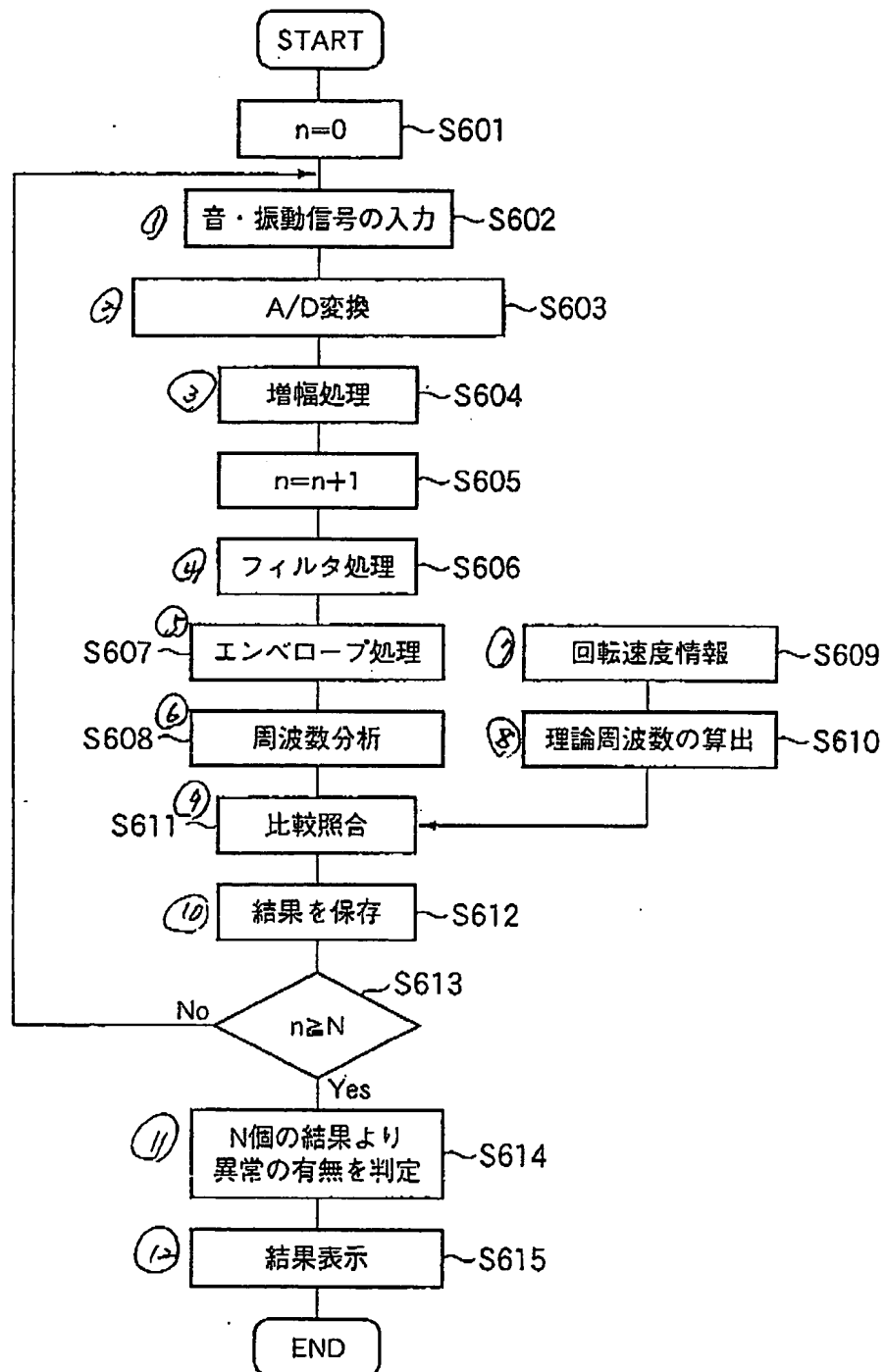


Fig. 41

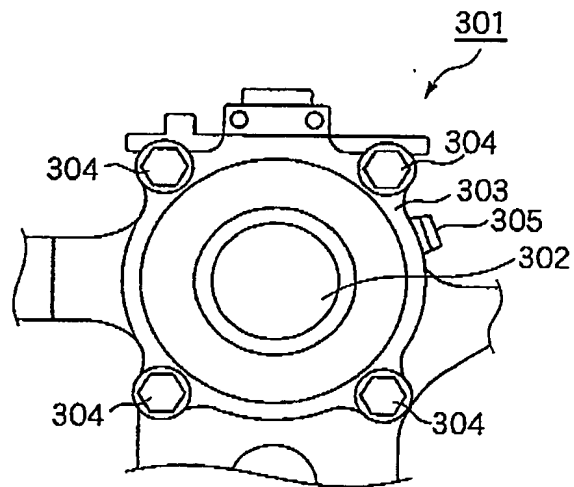


図42 Fig. 42

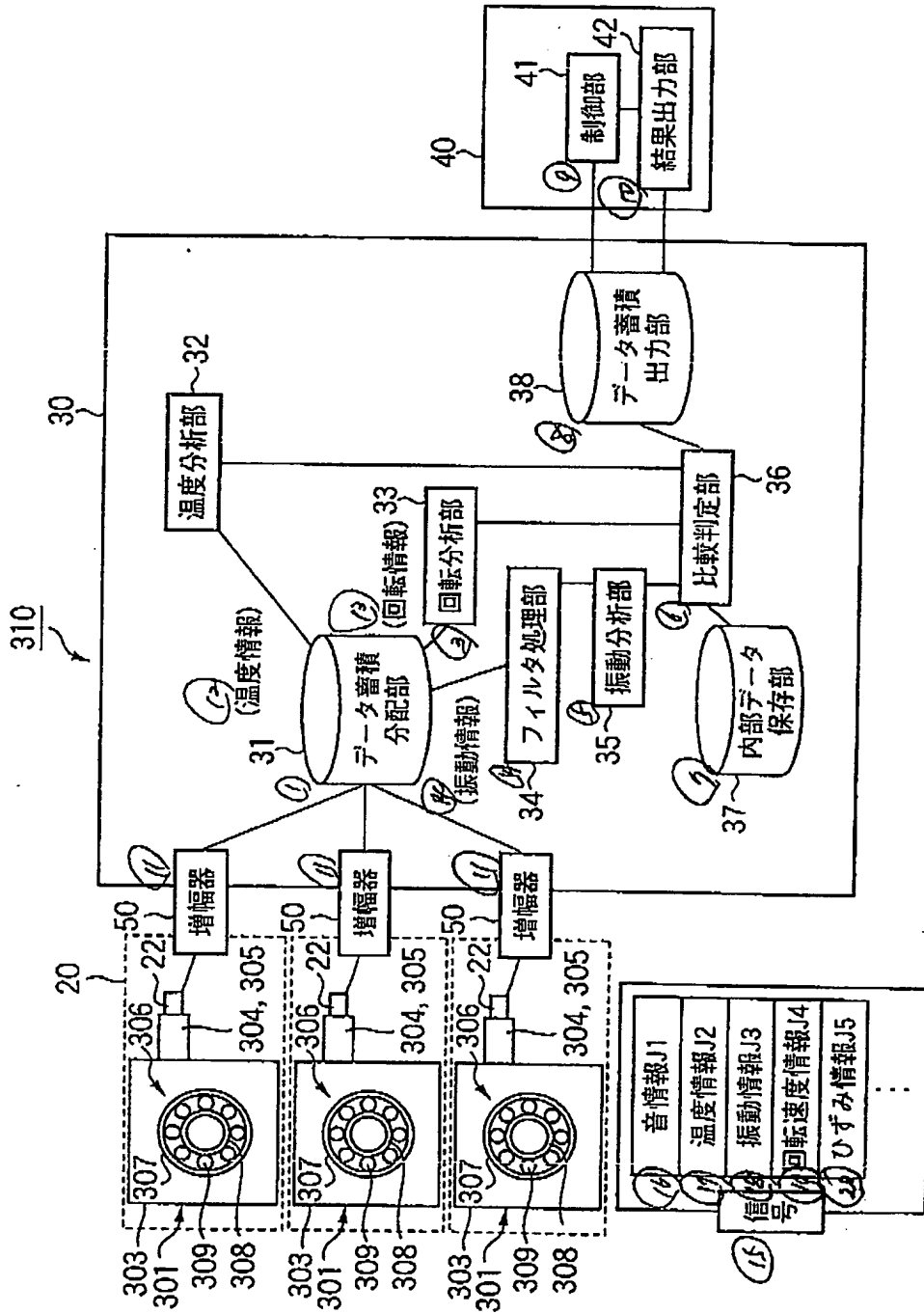


図43 Fig. 43

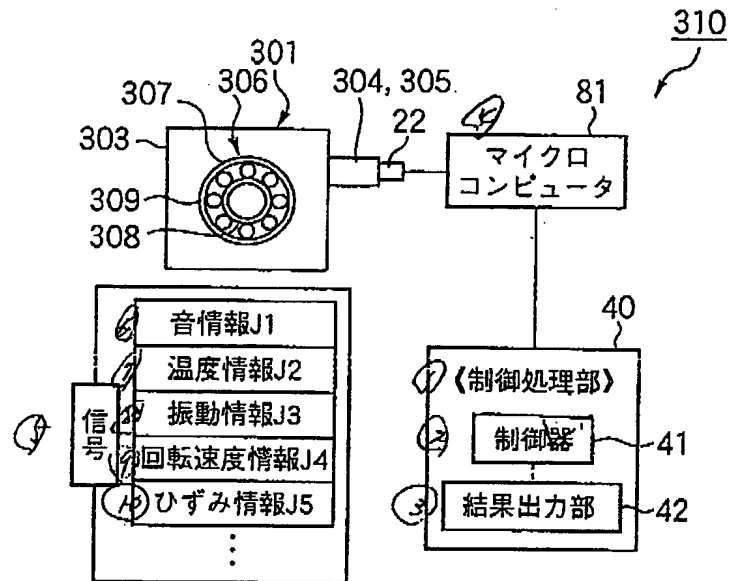


図44 Fig. 44

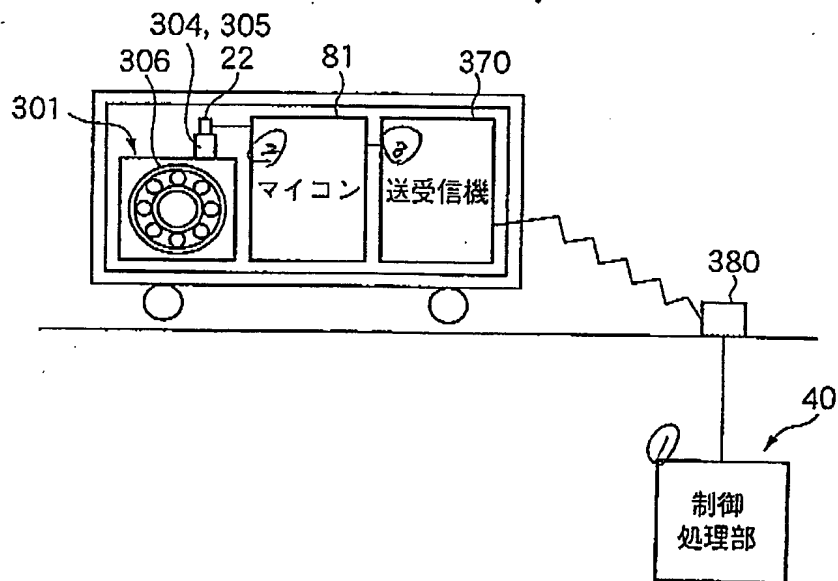




Fig. 45

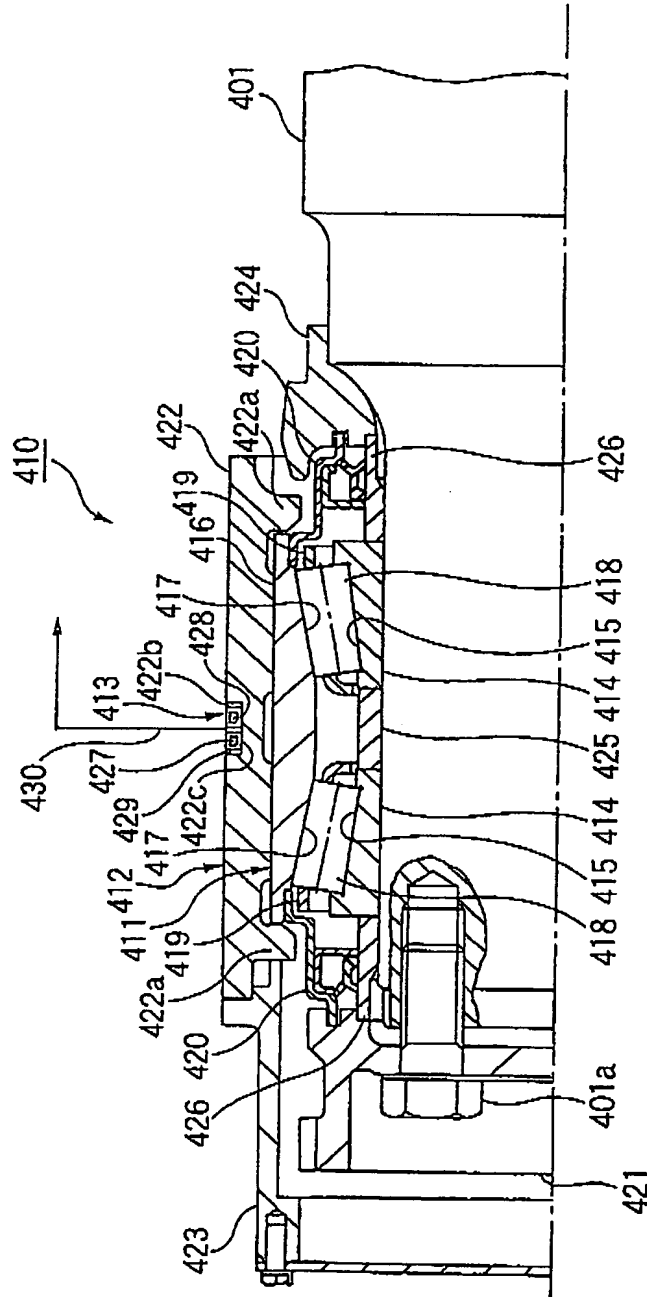


図46 Fig. 46

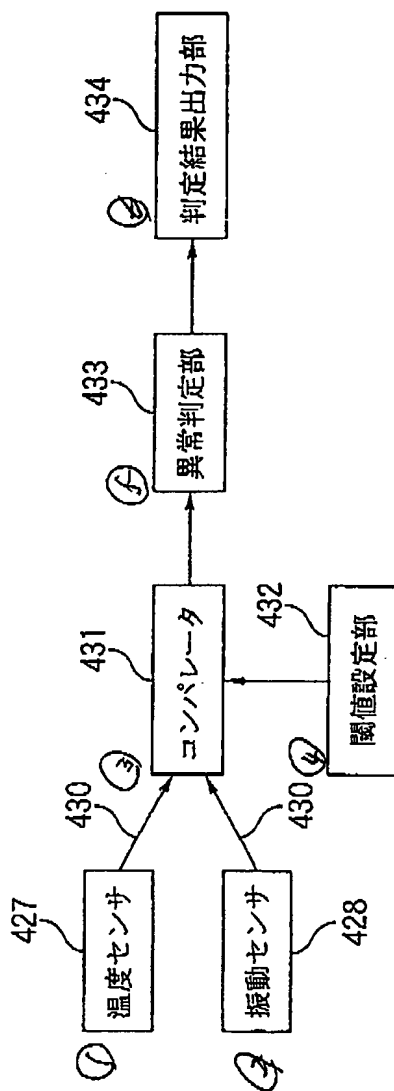


図47 Fig. 47

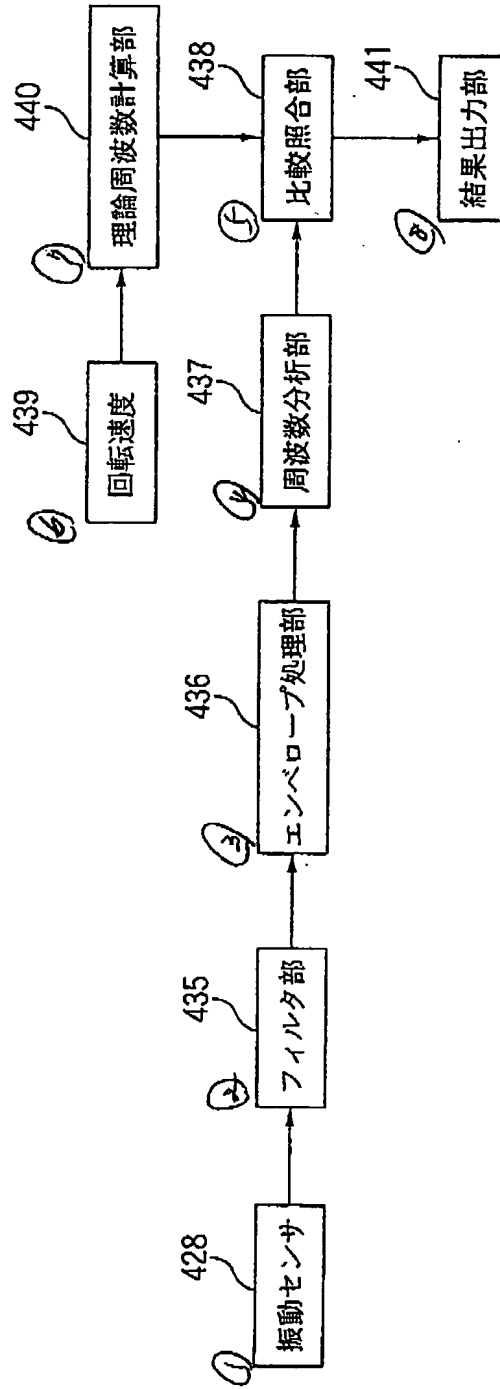


Fig. 48

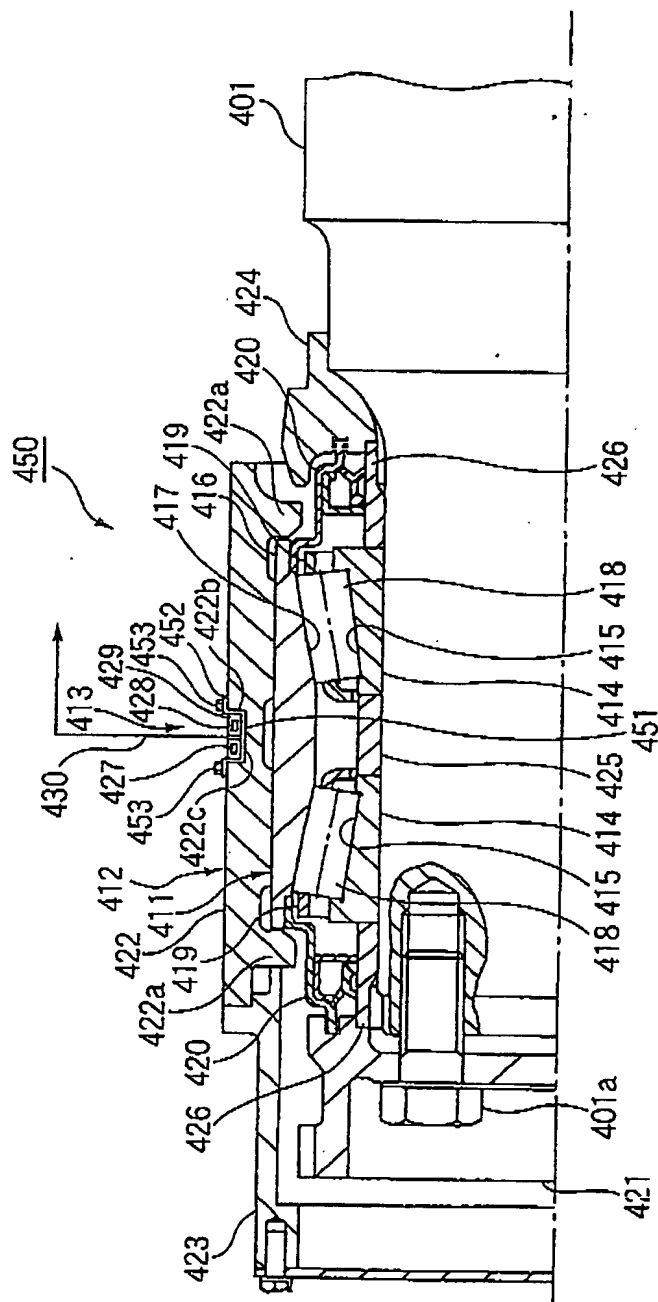


Fig. 49

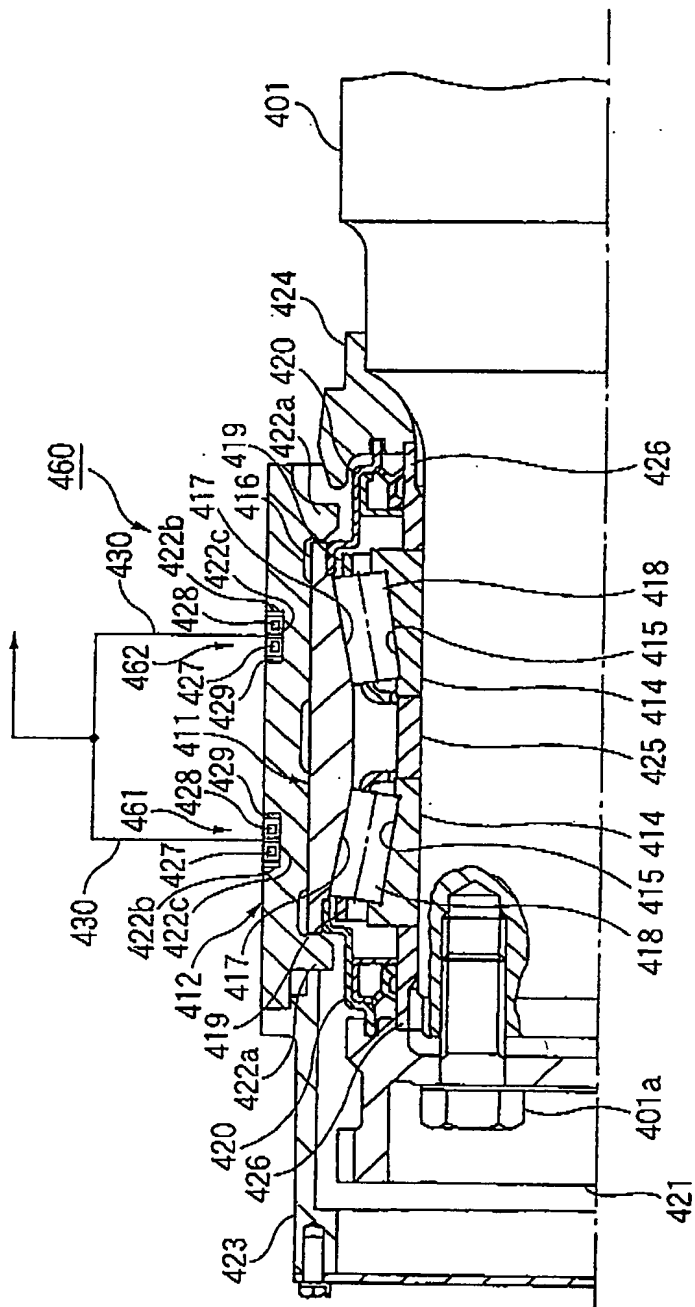


Fig. 50

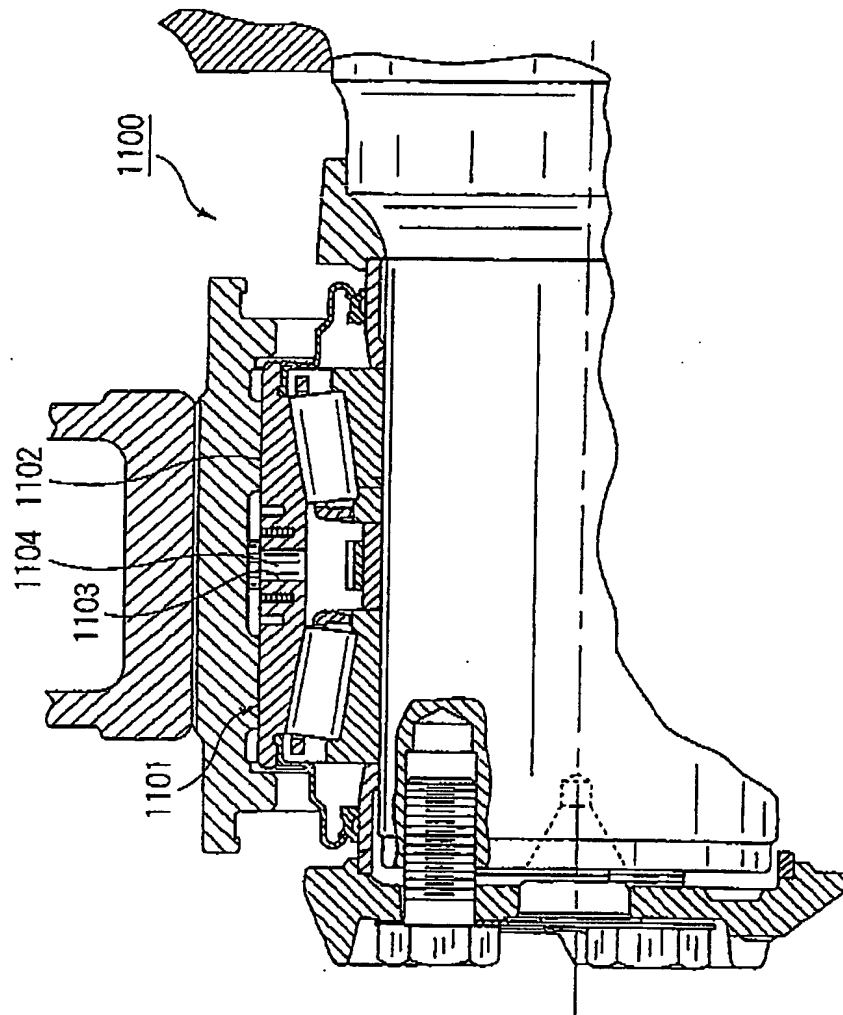


図51 Fig. 51

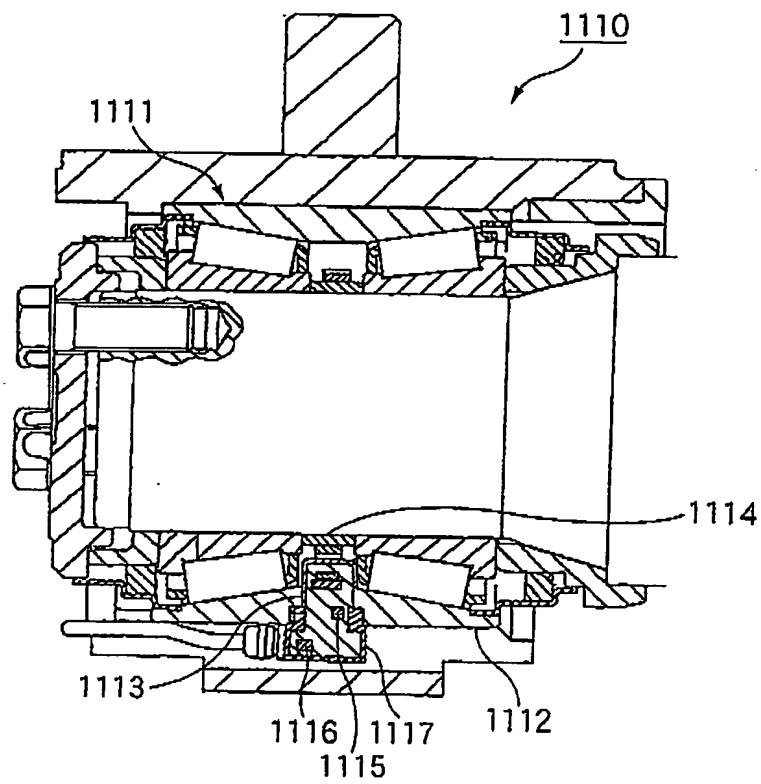


图52 Fig. 52

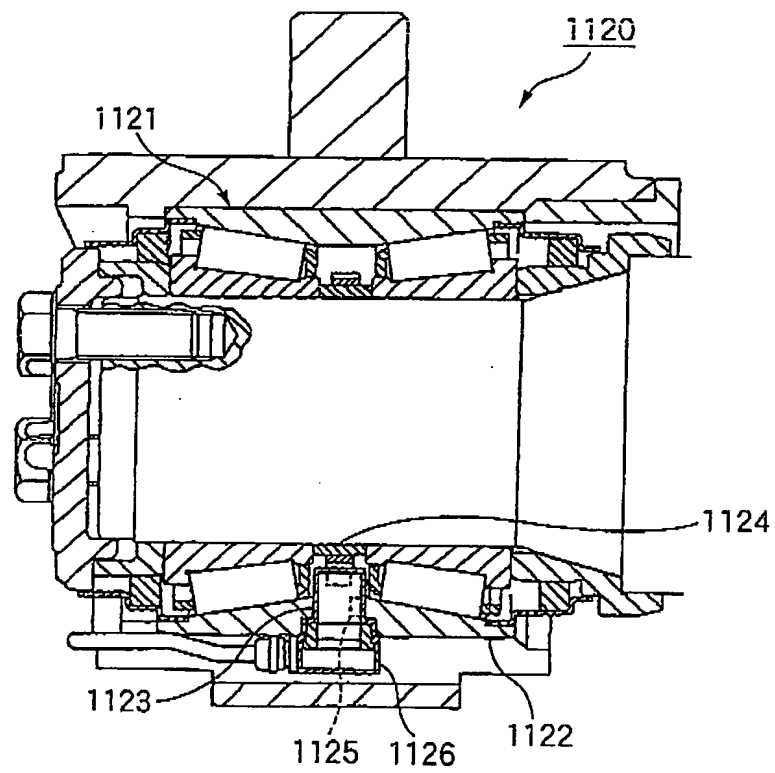




図53 Fig. 53

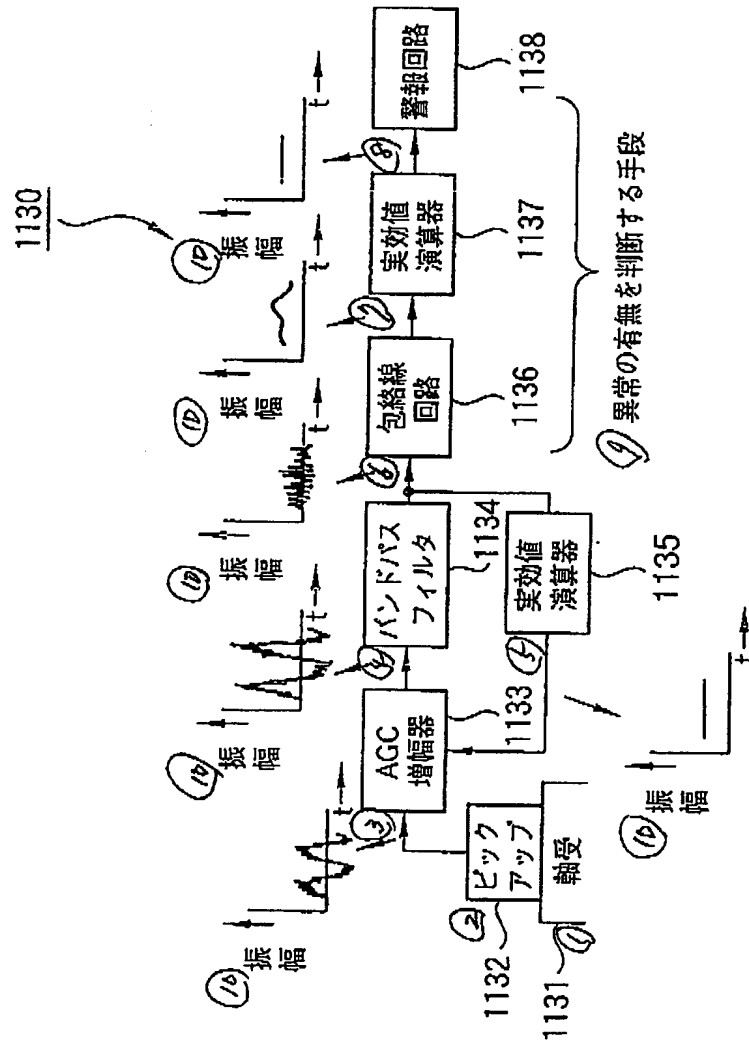


図54 Fig. 54

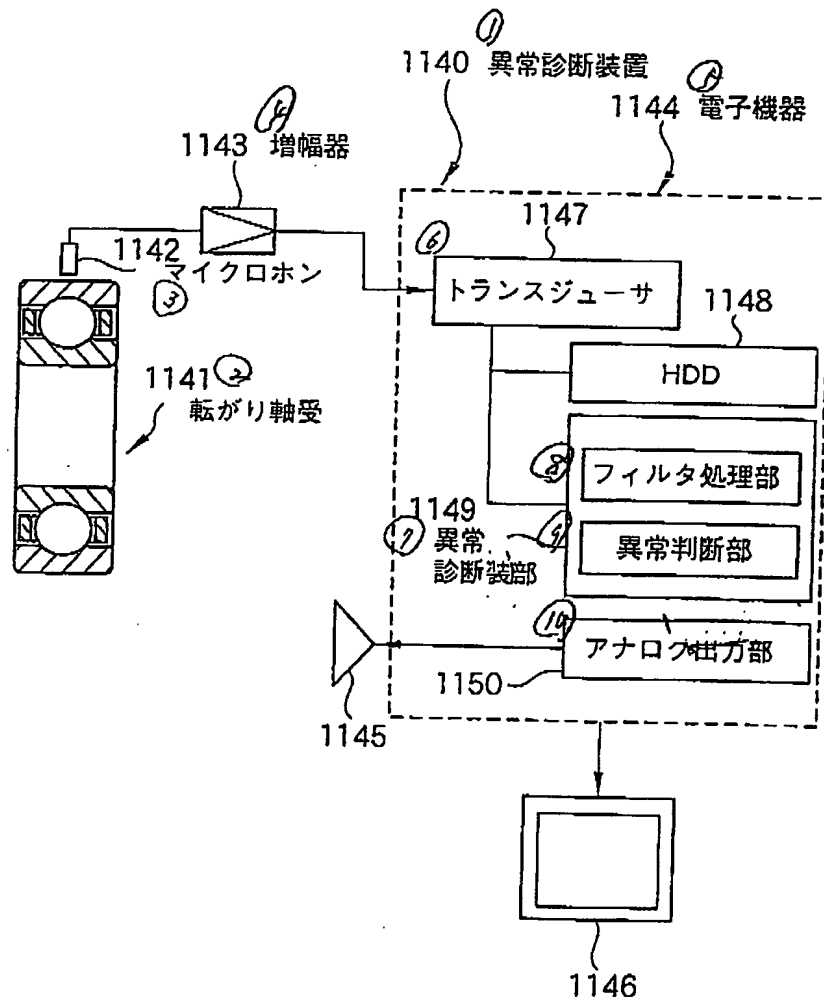
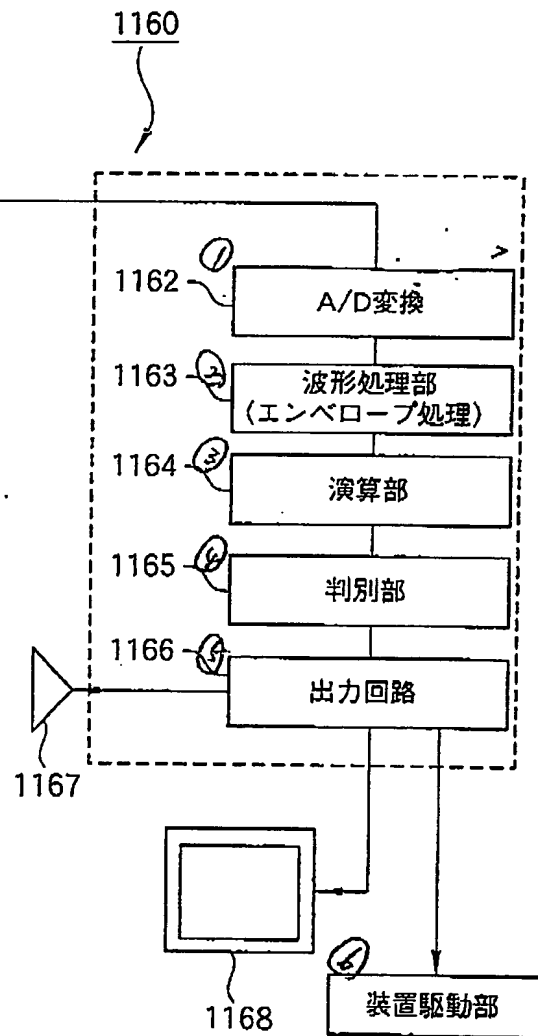


図55 Fig.55



## FIGS.1, 42:

- (1) data accumulating/distributing portion 31
- (2) temperature analyzing portion 32
- (3) rotation analyzing portion 33
- (4) filtering processing portion 34
- (5) vibration analyzing portion 35
- (6) comparing/deciding portion 36
- (7) internal data saving portion 37
- (8) data accumulating/outputting portion 38
- (9) controlling portion 41
- (10) result outputting portion 42
- (11) amplifier 50
- (12) (temperature information)
- (13) (rotation information)
- (14) (vibration information)
- (15) signals
- (16) sound information J1
- (17) temperature information J2
- (18) vibration information J3
- (19) rotation speed information J4
- (20) distortion information J5

## FIG.2(a):

- (1) temperature sensing element 22b
- (2) rotation sensing element 22c
- (3) vibration sensing element 22d

(4) To a calculating/processing portion 30

FIG.2(b):

(1) temperature sensing element 22b

(2) rotation sensing element 22c

(3) vibration sensing element 22d

(4) amplifier 22e

(5) amplifier 22f

(6) amplifier 22g

(7) To a calculating/processing portion 30

FIG.3:

(1) data accumulating portion 31a

(2) sampling reference setting portion 31b

(3) sampling portion 31c

(4) inputting portion 100

(5) To a temperature analyzing portion 32

(6) To a rotation analyzing portion 33

(7) To a filtering processing portion 34

FIG.4:

(1) flaw of a rolling bearing

(2) frequency after an enveloping process

(3) inner ring (Si)

(4) outer ring (So)

(5) rolling element (Sb)

(6) retainer (Sc)

(7) fr: inner ring rotation speed [Hz]

- (8)  $f_c$ : retainer rotation speed [Hz]
- (9)  $f_b$ : rolling element rotation speed [Hz]
- (10)  $d_m$ : pitch circle diameter [mm]
- (11)  $Z$ : number of rolling elements
- (12)  $D_a$ : rolling element diameter [mm]
- (13)  $\alpha$ : contact angle [degree]

**FIG.5:**

- (1) loading range A1
- (2) non-loading range A2

**FIG.6:**

- (1) time-variant waveform

**FIG.7:**

- (1) FFT spectrum

**FIG.8:**

- (1) envelope FFT spectrum
- (2) frequency component due to damage of the outer ring of the bearing

**FIG.9:**

- (1) sense sound/vibration signals (S101)
- (2) A/D conversion (S102)
- (3) save in a predetermined format (S103)
- (4) frequency analysis (S104)
- (5) select a filter bandwidth (S105)
- (6) filtering process (S106)
- (7) enveloping process (S107)
- (8) frequency analysis (S108)

- (9) calculate a RMS value (S109)
- (10) calculate a frequency due to abnormality of the bearing (S110)
- (11) extract an inner ring flaw component  $S_i$  ( $Z_{fi}$ ), an outer ring flaw component  $S_o$  ( $Z_{fo}$ ), a rolling element flaw component  $S_b$  ( $Z_{fb}$ ), and a retainer component  $S_c$  ( $Z_{fc}$ ) (S111)
- (12) calculate a reference value (S112)
- (13)  $S_i, S_o, S_b, S_c > \text{reference value}$  (S113)
- (14) No abnormality is generated in the bearing (S114)
- (15) identify the abnormal position  $S_i$  (inner ring flaw),  $S_o$  (outer ring flaw),  $S_b$  (rolling element flaw),  $S_c$  (retainer flaw) (S115)

FIGS. 10, 11, 12:

- (1) reference value

FIG. 13:

- (1) sense sound/vibration signals (S101)
- (2) A/D conversion (S102)
- (3) forming into a digital file (S103)
- (4) frequency analysis (S104)
- (5) select a filter bandwidth (S105)
- (6) filtering process (S106)
- (7) enveloping process (S107)
- (8) frequency analysis (S108)
- (9) calculate a peak value (S201)
- (10) calculate a frequency due to abnormality of the bearing (S202)
- (11) extract an inner ring flaw component  $S_i$  ( $Z_{fi}$ ), an outer ring flaw component  $S_o$  ( $Z_{fo}$ ), a rolling element flaw component  $S_b$  ( $Z_{fb}$ ), and a retainer component  $S_c$  ( $Z_{fc}$ ) (S111)

component Sc (fc) (S203)

(12) Do Si, So, Sb, Sc have a peak value ? (S204)

(13) No abnormality is generated in the bearing (S205)

(14) identify the abnormal position Si(inner ring flaw), So (outer ring flaw), Sb  
(rolling element flaw), Sc (retainer flaw) (S206)

FIG.14:

(1)  $\delta_1(=Y_1-Y_0)>0$  -①

$\delta_2(=Y_2-Y_1)<0$  -②

where A ( $X_0, Y_0$ ), B ( $X_1, Y_1$ ), C ( $X_2, Y_2$ ).

When ①, ② are satisfied and

$$dy/dx=(Y_1-Y_0)/(X_1-X_0)>1$$

or

$$dy/dx=(Y_2-Y_1)/(X_2-X_1)<-1$$

is satisfied,  $Y_1$  is decided as a peak.

FIG.15:

(1) Do the primary components coincide with each other ? (S201)

(2) Do the secondary components coincide with each other ? (S202)

(3) Do the secondary components coincide with each other ? (S211)

(4) Do the quaternary components coincide with each other ? (S212)

(5) No abnormality is generated (S321)

(6) The abnormality is generated (S321)

FIG.16:

(1) collate only the primary, secondary, quaternary components (flaw of the outer  
ring)

(2) (secondary)



(3) (quaternary)

FIG.17:

- (1) reference level  $L_0$  (RMS value  $f_1$ )
- (2) level difference

FIG.18:

- (1) a relationship between a size of flaking and a level difference
- (2) reference level dB
- (3) size of flaking mm

FIG.19:

- (1) calculate the abnormal frequency due to the abnormality in the bearing (S401)
- (2) extract a primary component due to the inner ring flaw, a primary component due to the outer ring flaw, a primary component due to the rolling element flaw, and a primary component due to the retainer (S402)
- (3) extract a natural-number multiple component due to the inner ring flaw, a natural-number multiple component due to the outer ring flaw, a natural-number multiple component due to the rolling element flaw, and a natural-number multiple component due to the retainer (S403)
- (4) comparing the primary component with respective natural- number multiple components by referring to reference value (S404)
- (5) Is the abnormality generated ? (S405)
- (6) The abnormality is generated. Identify the abnormal position (S406)
- (7) No abnormality is generated (S407)

FIG.20:

- (1) degree
- (2) level (dB)

- (3) criterion line
- (4) roller missing sound
- (5) The case where the flaw is generated

FIG.21:

- (1) calculate the abnormal frequency due to the abnormality in the bearing (S501)
- (2) calculate  $V_i$  and  $V_{RMS}$  (S502)
- (3) calculate a difference between  $V_i$ ,  $V_{RMS}$  or a quotient (S503)
- (4) Does the difference or the quotient exceed a reference value ? (S504)
- (5) The abnormality is generated. Identify the abnormality occurring location  
(S505)
- (6) No abnormality is generated (S506)

FIGS.22, 23, 24, 25:

- (1) frequency Hz
- (2) intensity

FIG.26:

- (1) temperature sensing element 52b
- (2) rotation sensing element 52c
- (3) vibration sensing element 52d
- (4) transmitting portion 52h
- (5) To the calculating/processing portion 30

FIG.27:

- (1) data accumulating portion 31
- (2) temperature analyzing portion
- (3) rotation analyzing portion
- (4) filtering processing portion 34

- (5) vibration analyzing portion
- (6) comparing/deciding portion 36
- (7) internal data saving portion 37
- (8) data accumulating/outputting portion 38
- (9) controlling portion 41
- (10) result outputting portion 42
- (11) receiving portion 60
- (12) (temperature information)
- (13) (rotation information)
- (14) (vibration information)
- (15) radio communication
- (16) signals
- (17) sound information J1
- (18) temperature information J2
- (19) vibration information J3
- (20) rotation speed information J4
- (21) distortion information J5

FIG.28:

- (1) (sensor built-in bearing) 21
- (2) <calculating/processing portion> 30
- (3) data accumulating/distributing portion 31
- (4) temperature analyzing portion 32
- (5) rotation analyzing portion 33
- (6) filtering processing portion 34
- (7) vibration analyzing portion 35

- (8) comparing/deciding portion 36
- (9) internal data saving portion 37
- (10) data accumulating/outputting portion 38
- (11) <controlling/processing portion> 40
- (12) controller 41
- (13) result outputting portion 42
- (14) signal transmitting/receiving device 63
- (15) information processing center
- (16) (temperature information)
- (17) (rotation information)
- (18) (vibration information)
- (19) signals
- (20) sound information J1
- (21) temperature information J2
- (22) vibration information J3
- (23) rotation speed information J4
- (24) distortion information J5
- (25) feedback

FIG.29:

- (1) (sensor built-in bearing) 21
  - (2) data accumulating/distributing portion 31
  - (3) temperature analyzing portion 32
  - (4) rotation analyzing portion 33
  - (5) filtering processing portion 34
  - (6) vibration analyzing portion 35
-

- (7) comparing/deciding portion 36
- (8) internal data saving portion 37
- (9) data accumulating/outputting portion 38
- (10) result outputting portion 42
- (11) <calculating/processing portion> 73
- (12) <controlling/processing portion> 75
- (13) (temperature information)
- (14) (rotation information)
- (15) (vibration information)
- (16) signals
- (17) sound information J1
- (18) temperature information J2
- (19) vibration information J3
- (20) rotation speed information J4
- (21) distortion information J5
- (22) remove and bring it to the calculating/processing portion

FIG.30:

- (1) <controlling/processing portion> 40
  - (2) controller 41
  - (3) result outputting portion 42
  - (4) <microcomputer> IC chip memory 81
  - (5) machinery facility 90
  - (6) <sensing processing portion>
  - (7) signals
  - (8) sound information J1
-

- (9) temperature information J2
- (10) vibration information J3
- (11) rotation speed information J4
- (12) distortion information J5

FIG.31:

- (1) data accumulating/distributing portion 31
- (2) temperature analyzing portion 32
- (3) rotation analyzing portion 33
- (4) filtering processing portion 34
- (5) vibration analyzing portion 35
- (6) comparing/deciding portion 36
- (7) internal data saving portion 37
- (8) <microcomputer> 81
- (9) (temperature information)
- (10) (rotation information)
- (11) (vibration information)

FIGS.32, 33:

- (1) <controlling/processing portion> 40
- (2) controller 41
- (3) result outputting portion 42
- (4) <microcomputer> IC chip memory 81
- (5) machinery facility 90
- (6) signals
- (7) sound information J1
- (8) temperature information J2

- (9) vibration information J3
- (10) rotation speed information J4
- (11) distortion information J5

FIG.34(a):

- (1) piezoelectric sensor signal
- (2) temperature data input
- (3) rotating pulse input

FIG.35(a):

- (1) temperature sensor 163
- (2) sensing circuit
- (3) impact sensor 183
- (4) amplifier filter 184
- (5) rotating pulse input

FIG.36:

- (1) machinery facility monitoring system 191
- (2) peripheral function
- (3) sensor signal output
- (4) diagnosed feature parameter output diagnosis result output

FIG.38:

- (1) <controlling/processing portion> 40
  - (2) controller 41
  - (3) result outputting portion 42
  - (4) <sensing processing portion>
  - (5) <microcomputer> IC chip memory 250
  - (6) signals
-

- (7) sound information J1
- (8) temperature information J2
- (9) vibration information J3
- (10) rotation speed information J4
- (11) distortion information J5

FIG.39:

- (1) data accumulating/distributing portion 31
- (2) temperature analyzing portion 32
- (3) rotation analyzing portion 33
- (4) filtering processing portion 34
- (5) vibration analyzing portion 35
- (6) internal data saving portion 37
- (7) <calculating/processing portion> 250
- (8) comparing/deciding portion 252
- (9) (temperature information)
- (10) (rotation information)
- (11) (vibration information)

FIG.40:

- (1) input sound/vibration signals (S602)
  - (2) A/D conversion (S603)
  - (3) amplifying process (S604)
  - (4) filtering process (S606)
  - (5) enveloping process (S607)
  - (6) frequency analysis (S608)
  - (7) rotation speed information (S609)
-



- (8) calculate a theoretical frequency (S610)
- (9) compare/collate (S611)
- (10) save the result (S612)
- (11) decide based on N results whether or not the abnormal is present (S614)
- (12) display the result (S615)

FIG.43:

- (1) <controlling/processing portion> 40
- (2) controller 41
- (3) result outputting portion 42
- (4) microcomputer 81
- (5) signals
- (6) sound information J1
- (7) temperature information J2
- (8) vibration information J3
- (9) rotation speed information J4
- (10) distortion information J5

FIG.44:

- (1) controlling/processing portion 40
- (2) microcomputer 81
- (3) transmitter/receiver 370

FIG.46:

- (1) temperature sensor 427
- (2) vibration sensor 428
- (3) comparator 431
- (4) threshold setting portion 432

(5) abnormality deciding portion 433

(6) decision result outputting portion 434

FIG.47:

(1) vibration sensor 428

(2) filter portion 435

(3) envelope proccssing portion 436

(4) frequency analyzing portion 437

(5) comparing/collating portion 438

(6) rotation speed 439

(7) theoretical frequency calculating portion 440

(8) result outputting portion 441

FIG.53:

(1) bearing 1131

(2) pickup 1132

(3) AGC amplifier 1133

(4) band-pass filter 1134

(5) RMS calculator 1135

(6) envelope circuit 1136

(7) RMS calculator 1137

(8) alarm circuit 1138

(9) means for deciding whether or not the abnormality is present

(10) amplitude

FIG.54:

(1) abnormality diagnosis system 1140

(2) rolling bearing 1141

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- (3) microphone 1142
- (4) amplifier 1143
- (5) electronic device 1144
- (6) transducer 1147
- (7) abnormality diagnosing portion 1149
- (8) filtering processing portion
- (9) abnormality deciding portion
- (10) analog outputting portion 1150

FIG.55:

- (1) A/D conversion 1162
- (2) waveform processing portion (enveloping process) 1163
- (3) calculating portion 1164
- (4) deciding portion 1165
- (5) outputting portion 1166
- (6) system driving portion